

Isolation, Encapsulation, Stability and Characteristics of Thylakoid from Suji Leaves (*Dracaena angustifolia* Roxb.) as Natural Food Coloring Agent

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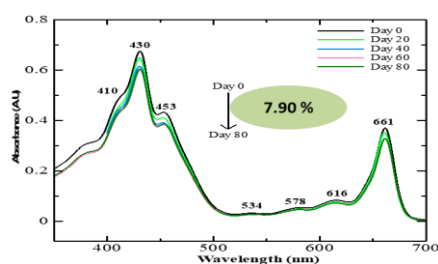
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Abstract

Suji (*Dracaena angustifolia* Roxb.) is one kind of Indonesian typical plants which can be used as natural green food coloring agent. The susceptibility of natural pigment to external environment forces the protection in order to prolong its shelf life. Encapsulation has been known in the art of food preparation to protect several ingredients including food coloring agent. The objective of this study was to observe the method for isolation and encapsulation of thylakoid, and to investigate the stability and characteristics of thylakoid of suji leaves encapsulated in maltodextrin during dark storage at 30, 45, and 60 °C. The degradation of the encapsulated pigments was identified through chromametric analysis which resulted in the increase of L* (lightness), a* (redness), and b* (yellowness) values. In addition, it was also indicated by the decrease of total chlorophyll (TC) which was determined using spectrophotometer. Chromatography analysis confirmed the presence of four major peaks in the fresh encapsulated thylakoid powder and five major peaks in the encapsulated thylakoid powder stored at the highest temperature (60 °C), with Chl a as the dominant pigments in both powder. The vivid green powder was able to preserve its color without any obvious change to an untrained eye up to 40 d of storage at 30 °C, becoming a promising ingredient to replace the synthetic colorants.



Short Description

Natural green food colorants from thylakoid of suji leaves contained chlorophyll pigments which degraded by less than 10 % after 80 days of storage at 30 °C in dark condition. It is predominated by chlorophyll groups (Chl a and Chl b), with the presence of Pheo a after certain days of storage at 60 °C. Furthermore, it could show its greenness for more than a month at 30 °C.

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INTRODUCTION

Food coloring is one of food additives frequently added into food products such as candy, snacks, beverages, and some other products. Color, one of sensory qualities, not only plays an important role in determining selection and acceptance of food products but also stimulation of appetite, satisfaction, and ingestion [1]. In food industries, color has become indicative parameter used in quality control which determine appearance and sale indicator. Artificial food coloring has been applied by food industries as it has been known to provide durable bright and strong color. On the other hand, natural food coloring which is more susceptible to external environment such as light,

oxygen, temperature, and pH [2] has been more underrated in use as it also provides dull color. According to the International Association of Color Manufacturers in [3], artificial food coloring has enhanced the intensity of natural colors, causing natural colors to become virtually colorless. However, there are impacts especially on human health that should be concerned caused by consuming artificial food coloring. In 2011, FDA (Food and Drug Administration) established legal limits for cancer causing contaminants in dyes. Furthermore, regarding to artificial green color, FD&C Green 3 has been found to cause significant increases in bladder transitional cell or urothelial neoplasms and testes Leydig's tumors in high-dose male rats [4].

Heriyanto, et al. (2019).



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Suji (*Dracaena angustifolia* Roxb.) is one kind of Indonesian typical plants which has been traditionally used as natural green food coloring. The presence of chlorophyll and other minor pigments in the leaves of suji, which is attached to proteins in the thylakoid membranes, provides antioxidant activity which is useful for health. Hsu *et al.* [5] revealed that chlorophyll compounds including pheophytins could protect the body through multiple chemical mechanisms and act as antioxidant which could prevent lipid peroxidation and oxidative damage on DNA. The susceptibility of natural pigment to external environment forces the protection in order to prolong the shelf life. In addition, the protection also plays an important role in simplifying the application of natural food colorant without pre-treatment such as squeezing the leaves to obtain chlorophylls.

Encapsulation is a technology that has been developed to protect active substances including pigments from external environment. It is a physical coating process which surrounds an active substance as core material with an encapsulating agent as wall material, forming a capsule of isolation of the active material [6]. In this study, the wall material used was maltodextrin which could reduce stickiness and agglomeration problems during storage which in turn could produce powder form [7,8], improving the solubility of the dry products. In addition, encapsulation could increase the stability of the encapsulated materials, proved by a number of researches. Lin *et al.* [9] found that encapsulated astaxanthin was more stable than those without encapsulation which shows that the matrix formed by encapsulating agent was able to protect the materials from the thermal degradation and oxygen. This study was conducted to observe the stability of freeze dried microencapsulated pigment in the thylakoid obtained from suji leaves during dark storage at 30 °C, 45 °C, and 60 °C.

EXPERIMENTAL

General

Suji (*Dracaena angustifolia* Roxb.) used in this study was obtained from Botanical garden of Universitas Ma Chung, East Java, Indonesia. Maltodextrin with a dextrose equivalent (DE) of 10-12 % (Yishui Dadi Corn Developing Co., Ltd.) was utilised as the encapsulating agent. Solution used to extract thylakoid from suji leaves was a mixture of sucrose (Sigma, 99.5%), anhydrous MgCl₂ (Chameleon, 99%), and NaCl (Merck). Acetone (Merck), diethyl ether (Merck), methanol (Merck) and tert-Butyl methyl ether (Merck) were used to conduct analysis regarding to pigments extraction and identification.

The extraction of suji leaves was conducted by using a juicer (Philips), after which the encapsulated extract was freeze dried under a freeze dryer (Labconco 220). Pigment analysis in term of absorption spectrum measurement was carried out by using a spectrophotometer (Shimadzu) while pigment identification was conducted under a High Performance Liquid Chromatography (Shimadzu). This analysis was conducted after the samples were stored in a climate chamber (Mettler, ICH 110 L). The change in color during storage was observed using a Colorflex EZ spectrophotometer (HunterLab).

Sample Preparation and Thylakoid Isolation

Adequate amount (15 g) of suji leaves (*Dracaena angustifolia* Roxb.) were washed and cut, followed with crushing the leaves with juicer in thylakoid extracting solution consisting of 13 %

sucrose solution (w/v), 0.01 % anhydrous MgCl₂ (w/v) and 0.01 % NaCl (w/v). The extract of suji leaves which contained thylakoid and pigment protein complex was filtered by using cloth and centrifuged at 6 000 g, 4 °C, for 15 min. The centrifugation was repeated for five times until there was no precipitation of thylakoid in the filtrate. The thylakoid was collected and prepared for encapsulation.

Encapsulation

The thylakoid was encapsulated with maltodextrin (1 : 2, w/w) and kept under stirring for about 10 min at 4 °C until the mixture was homogenized. The solution was kept frozen overnight and subjected into freeze drying (Labconco Co., USA) at -45 °C under high vacuum conditions (around 0.03 mBar). Dried material, with moisture content less than 10 %, was ground and sieved at 80 mesh in order to obtain particle size about 250 µm. The pigment powder or microcapsule was directly stored at -15 °C under inert condition (added N₂ gas) until it is used for further analysis.

Storage Condition

Encapsulated pigment powder (2 g) was placed in 5 mL brown gas bottles, followed with sealing after sufficient addition of inert gas. The series of samples were stored at 30 °C (80 d), 45 °C (30 d) and 60 °C (4 d) in climate chamber (Mettler, ICH 110 L), each of which was observed five times (I, II, III, IV, and V). At 30 °C, the observation was conducted on 0, 20, 40, 60, and 80 d, while at 45 °C, it was carried out on 0, 5, 10, 20, and 30 d. At 60 °C, the observation was conducted on 0, 1, 2, 3, and 4 d. The different observation days were carried out since this study was focusing on the degradation of the total chlorophyll in relation to its stability during certain days of storage. The data of moisture content, color, surface and total pigment absorption spectrum were also periodically recorded.

Analysis of Pigment

Surface chlorophyll (SC) was determined by direct extraction of 0.1 g encapsulated thylakoid powder with 1 mL acetone in a vortex for 20 s. After centrifugation at 10 000 rpm for 1 min, the supernatant was collected and subjected to measurement of pigment absorption spectrum using spectrophotometer (UV-1700, Shimadzu). Meanwhile, total chlorophyll (TC) was observed by firstly breaking the capsules of 0.1 g encapsulated pigment powder using 5 mL water. The mixture was homogenized in a vortex for 1 min, followed by exhaustive extraction with acetone and diethyl ether to collect the total pigment for pigment absorption spectrum analysis. Encapsulation efficiency (EE) was determined through formulation (1): % EE = [(TC-SC)/TC] × 100 % [10]. Identification and quantification according to the peak area of pigment were obtained through separation by a Shimadzu high-performance liquid chromatograph using YMC C30 reversed-phase (Wilmington, MA, USA) column (150 x 4.6 mm I.D.), equipped with photodiode array detector, with mobile phase A (MeOH : MTBE : H₂O = 81 : 15 : 4) at 0 min and mobile phase B (MeOH : MTBE : H₂O = 6 : 90 : 4) at 70 min, detected at 430 nm.

Determination of Total Chlorophyll

Absorption spectra of crude pigment extract, in the range of 300 nm to 800 nm, were recorded by using UV-1700 spectrophotometer (Shimadzu). Concentration of total

chlorophyll was determined based on the equation of Lichtenthaler [11].

Color Measurement

Color of the encapsulated pigment was measured using ColorFlex® EZ (HunterLab) under the same light conditions, at room temperature, and repeated in triplicate. The results were expressed in terms of L^* (lightness), a^* (redness), and b^* (yellowness) according to Commission Internationale de l'Eclairage (CIELAB system). The instrument was standardized using a standard white tile ($L^* 92.93$, $a^* -0.92$, $b^* 1.48$) prior to use. The change of color over time was calculated as delta E (ΔE) with the equation as follow:

$$\Delta E = \sqrt{(L_f - L_i)^2 + (a_f - a_i)^2 + (b_f - b_i)^2} \quad (2)$$

L_f , a_f and b_f were the initial for day 0 values while L_i , a_i , and b_i were the initial for the readings obtained each time of analysis. There were five classification of value obtained which determined the change of the color that could be visually detected by trained and untrained eyes. Those were normally invisible difference (0-1), very small difference only obvious to a trained eye (1-2), medium difference obvious to an untrained eye (2-3.5), obvious difference (3.5-5) and very obvious difference (> 6) [12].

RESULTS AND DISCUSSION

Total chlorophyll content

Suji leaves (*Dracaena angustifolia* Roxb.) have been known to provide high amount of chlorophyll which could play an important role as an antioxidant agent. Istichomah *et al.* [13] found that chlorophyll content in suji leaves was $2053.80 \mu\text{g} \cdot \text{g}^{-1}$ wet weight (ww), higher than that in pandan leaves which was $555.43 \mu\text{g} \cdot \text{g}^{-1}$ wet weight (ww) [14]. In this study, TC content in suji leaves was measured, resulting in $2959.25 \pm 43.69 \mu\text{g} \cdot \text{g}^{-1}$ wet weight (ww) which was higher than the result shown in the previous study. The difference in the level of chlorophyll in plants as well as those of the same species is strongly dependent on photosynthesis process which is influenced by environmental growth conditions including variation in the presence of soil nutrients such as magnesium, nitrogen and iron [15,16,17].

Table 1. Reduction of total chlorophyll (TC) in encapsulated thylakoid of suji leaves (*Dracaena angustifolia* Roxb.) powder at different temperature of storage, 30 °C, 45 °C and 60 °C, during the period of storage

Time (d)	Reduction of total chlorophyll (%)		
	60 °C	45 °C	30 °C
I	100	100	100
II	93.09	90.95	99.16
III	88.63	87.97	96.43
IV	86.19	81.90	95.40
V	73.31	77.88	92.10

Encapsulation of pigment is one method to prolong the shelf life of pigment as it could protect pigment against some external environment factors such as oxygen, temperature, light, and pH.

The efficiency of encapsulation (% EE), defined as the degree of encapsulated pigment especially chlorophyll, was calculated in the range of 90.19 % to 95.19 % at all temperature of storage. This signifies that high amount of chlorophyll was able to be coated by the encapsulating material. The result shown in this study was higher than the study conducted by Zaidel *et al.* [18] which used the same encapsulating agent, which was around 71.67 % to 75 % although the addition of maltodextrin was five times higher than this present study. The presence of thylakoid membrane might provide double protection for the chlorophyll which in turn diminished the degradation of chlorophyll as Chl a and b are properly formed and incorporated into the thylakoid membranes and associated photosystems [19].

In this study, in order to know the stability of pigment, the microcapsule was kept in the climate chamber at different temperature, 30, 45 and 60 °C. At 60 °C, TC was in the range of $1935.15 \pm 43.45 \mu\text{g} \cdot \text{g}^{-1}$ (dw) to $2639.79 \pm 7.35 \mu\text{g} \cdot \text{g}^{-1}$ (dw) while at 45 °C it ranged from $1961.86 \pm 41.34 \mu\text{g} \cdot \text{g}^{-1}$ (dw) to $2518.96 \pm 39.06 \mu\text{g} \cdot \text{g}^{-1}$ (dw). At temperature of 30 °C, TC was in the range between $2174.69 \pm 62.24 \mu\text{g} \cdot \text{g}^{-1}$ (dw) and $2361.22 \pm 16.34 \mu\text{g} \cdot \text{g}^{-1}$ (dw).

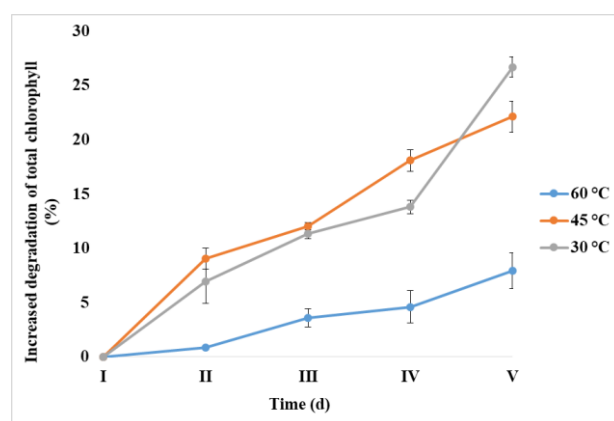


Figure 1. Percentage degradation of encapsulated thylakoid of suji leaves (*Dracaena angustifolia* Roxb.) powder at different temperature of storage, 30 °C, 45 °C and 60 °C, during the period of storage

In Table 1, it can be seen that from 100 % of TC, the microcapsules could provide TC by 73.31 % (at 30 °C), 77.88 % (45 °C) and 92.10 % (60 °C) at the end of observation time. This means that TC in encapsulated thylakoid decreased with time shown through the increase in the percentage degradation of TC (Figure 1), with the highest decrease was provided by temperature of 60 °C (26.69 ± 0.94 %) on the day 4, followed by 45 °C (22.12 ± 1.43 %) on the day 30 and 30 °C (7.90 ± 1.65 %) on the day 80. A number of studies have reported that temperature influences the degradation rate of pigment. Comparing with previous study about stability of chlorophyll in yerba mate leaves, Montiel and Avanza (1996) cited in Morawicki *et al.* [20] revealed that chlorophyll content decreased by 60 % at the storage temperature of 30 °C in 40 d. Meanwhile, the encapsulated pigment was decreased by 3.57 % at the same temperature and day of storage. This shows that encapsulation was able to protect the pigment by 20 times at 30 °C.

The degradation rate of pigment in the encapsulated thylakoid powder can also be seen in Figure 2 which shows spectral evolution during storage at 30 °C, 45 °C, and 60 °C. Chlorophylls have two major absorption bands in the visible

range, Qy (red band) and Soret (blue band) [21]. The figure represents that chlorophyll (Chl) *a* is located at 661 nm (Qy) and 430 nm (Soret), while the presence of Chl *b* was shown by small shoulder at 453 nm (Soret). The dissolved Chl *a* in acetone is located in the spectral range between the Soret and Qy bands at 534 nm, 578 nm and 616 nm. Meanwhile, pheophytin (Pheo) *a*, the derivative product of Chl *a*, has absorption spectrum of Soret at 410 nm [21].

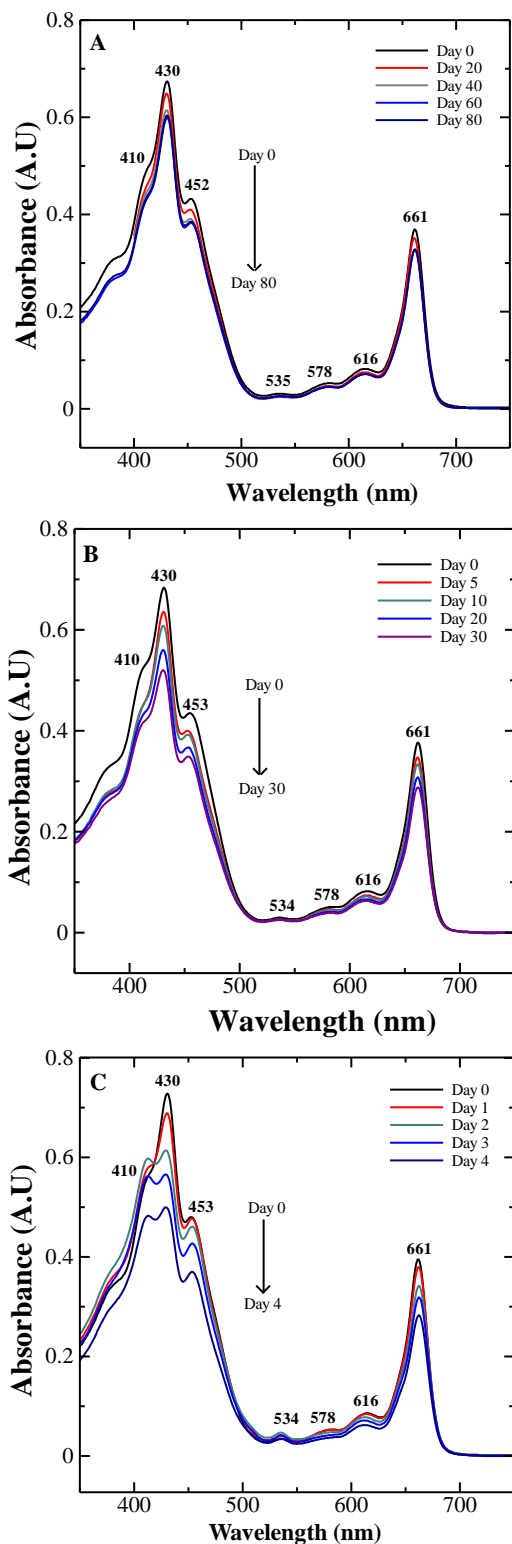


Figure 2. Absorption spectra of crude pigment extract from encapsulated thylakoid of suji leaves (*Dracaena angustifolia* Roxb.) powder at different temperature of storage, 30 °C (A), 45 °C (B) and 60 °C (C) during the period of storage

Figure 2A and 2B represent the reduction of absorbance value at the two major absorption bands which indicated the degradation of pigment during storage and this was accelerated by the higher temperature. Since the spectra shape and the maximum absorbance wavelength (λ_{max}) of crude pigment extract did not show any change, this means that there was no degradation products presented during storage. Meanwhile, at the temperature of storage 60 °C (Figure 2C), at the first 2 d of observation it can be seen that the absorbance value of Chl *a* was decreased with time while Pheo *a* as product degradation was increased, shown through the increase in absorbance value at soret band (410 nm). This shows the susceptibility of Chl *a* to heat treatment. According to the research conducted by Schwartz & Von Elbe [22], the activation energy of Chl *a* was higher than Chl *b* which means that less change of temperature is sufficient to rapidly degrade Chl *a*. In addition, Schwartz & Lorenzo [23] argued that heat treatment allows the degradation of chlorophyll into pheophytin due to the release of central magnesium from the chlorophyll ring and replaced by two hydrogen ions. Furthermore, the absorption spectrum was significantly decrease until day 4 which might be caused by the continuity of pigment degradation.

Pigment identification

Regarding to identification of pigments, four major peaks were presented in the fresh encapsulated thylakoid powder after chromatographic separation. Meanwhile, five major peaks were found in the encapsulated thylakoid powder stored at the highest temperature (60 °C) (Figure 3).

The identification of pigments was in accordance to the study of Taylor *et al.* [24] and Fernandes *et al.* [25], as shown in Table 2. Table 2 represents pigments content in the fresh encapsulated thylakoid powder and the encapsulated thylakoid powder stored at the highest temperature (60 °C). In the fresh microcapsules, calculated through area of each peak normalised with the dry weight of microcapsules, the most dominant pigment was shown by Chl *a* ($109\,347.84 \pm 541.84$ area \cdot g⁻¹ dw) which appeared at min 12.57 (peak 4), followed by the second highest pigment, Chl *b*, at min 8.72 (peak 2) with $23\,832.68 \pm 295.28$ area \cdot g⁻¹ dw. In plants, carotenoids also occurs abundantly alongside with chlorophyll in order to aid photosynthesis and phototaxis and this role is conducted by lutein, neoxanthin, violaxanthin and β -carotene [25,26]. In this study, two carotenoids were identified. Minor carotenoid (neoxanthin) (peak 1), amounted to $9\,464.89 \pm 237.21$ area \cdot g⁻¹ dw, was present as the fourth dominant pigment (min 4.98) while the second carotenoid which was lutein (peak 3, min 9.04) was appeared very close to Chl *b*, accounted for $23\,699.55 \pm 480.90$ area \cdot g⁻¹ dw.

In the heated encapsulated thylakoid powder, similar to fresh powder, Chl *a* was the highest pigment, however, it was appeared with lower area and forwarded retention time, $81\,766.48 \pm 666.51$ area \cdot g⁻¹ dw (peak 4); min 12.07. On the other hand, the area of Chl *b* (peak 2, min 8.32) was found to be lower than that of lutein (peak 3, min 8.63), $22\,372.68 \pm 295.68$ area \cdot g⁻¹ dw and $24\,123.39 \pm 962.69$ area \cdot g⁻¹ dw, respectively. Meanwhile, pheophytin (Pheo) *a*, which was not identified in the fresh powder, was presented as the fourth highest pigment ($15\,566.065 \pm 633.90$ area \cdot g⁻¹ dw) (peak 5) at min 23.67, followed by neoxanthin (peak 1) which increased with $12\,300.19 \pm 616.31$ area \cdot g⁻¹ dw at min 4.74.

Table 2. Identification of pigments of fresh encapsulated thylakoid powder and heated encapsulated thylakoid powder

Peak no.	Retention time (min)		Area (area · g ⁻¹ dw) ± SD		λ _{max} (nm)		Pigment name	Reference
	Fresh powder	Heated powder	Fresh powder	Heated powder	Fresh powder	Heated powder		
1	4.98	4.74	9 464.89 ± 237.21	12 300.19 ± 616.31	413,436,465	413,436,464	Neoxanthin	413,435,464 [24]
2	8.72	8.32	23 832.68 ± 295.28	22 372.68 ± 414.64	-468,650	-467,650	Chl <i>b</i>	-469,652 [24]
3	9.04	8.63	23 699.55 ± 480.90	24 123.39 ± 961.69	-445,472	-445,472	Lutein	(422),443,470 [24]
4	12.57	12.07	109 347.84 ± 541.13	81 766.48 ± 666.51	-431,665	-431,665	Chl <i>a</i>	-431,665 [24]
5	-	23.67	-	15 566.06 ± 633.90	-	-409,666	Pheo <i>a</i>	-408,665 [25]

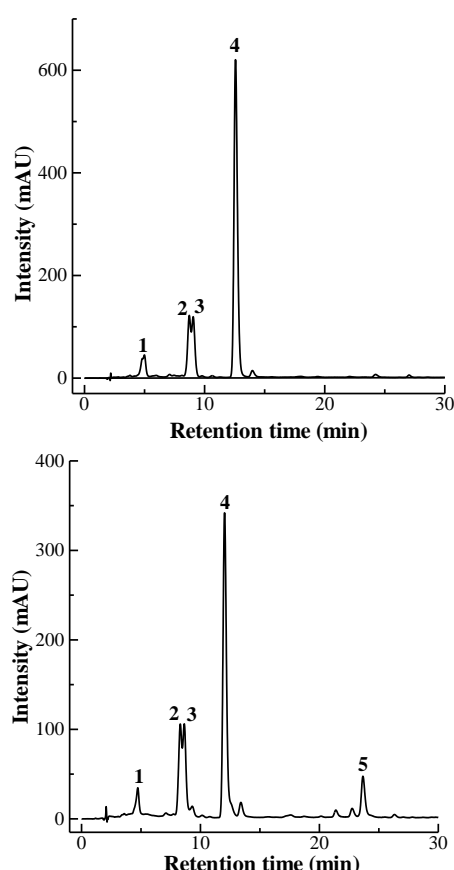


Figure 3. Chromatographic separation of the major pigments on fresh (A) and heated (B) encapsulated thylakoid of suji leaves (*Dracaena angustifolia* Roxb.) powder, performed in YMC C30 reversed-phase column, detected at 430 nm.

The susceptibility of Chl *a* to heat treatment was proven in this study as it can be seen that this pigment was decreased by 25 % while Chl *b* was less than 10 %. This is supported by some studies related to the susceptibility of Chl *a* compared to Chl *b*, one of them is the study of Schwartz & Von Elbe [22]. In addition, in the heated microcapsules, pheophytin *a* was found as a result of heat treatment. The substitution of the magnesium ion in the porphyrin ring with the hydrogen ions can transform the chlorophylls to their corresponding pheophytins following the simultaneous actions of oxygen, light, weak acids, enzymes and heat treatment [27,28].

According to Fernandes *et al.* [25], hydroxypheophytin and pheophytin was identified with the same wavelength (λ_{max}), 409 nm and 666 nm. Hydroxypheophytin is oxidized pheophytins with the hydroxy group located at C13 [25] which is more polar than pheophytin due to the presence of the group. It will be least retained in the column and eluted first, resulting in the shorter retention time. Therefore, pheophytin was assumed as the fourth

dominant pigment in the heated encapsulated thylakoid powder as there was no other dominant peaks found after Chl *a* and hydroxypheophytin might not be formed at 60 °C, at a short time (4 d).

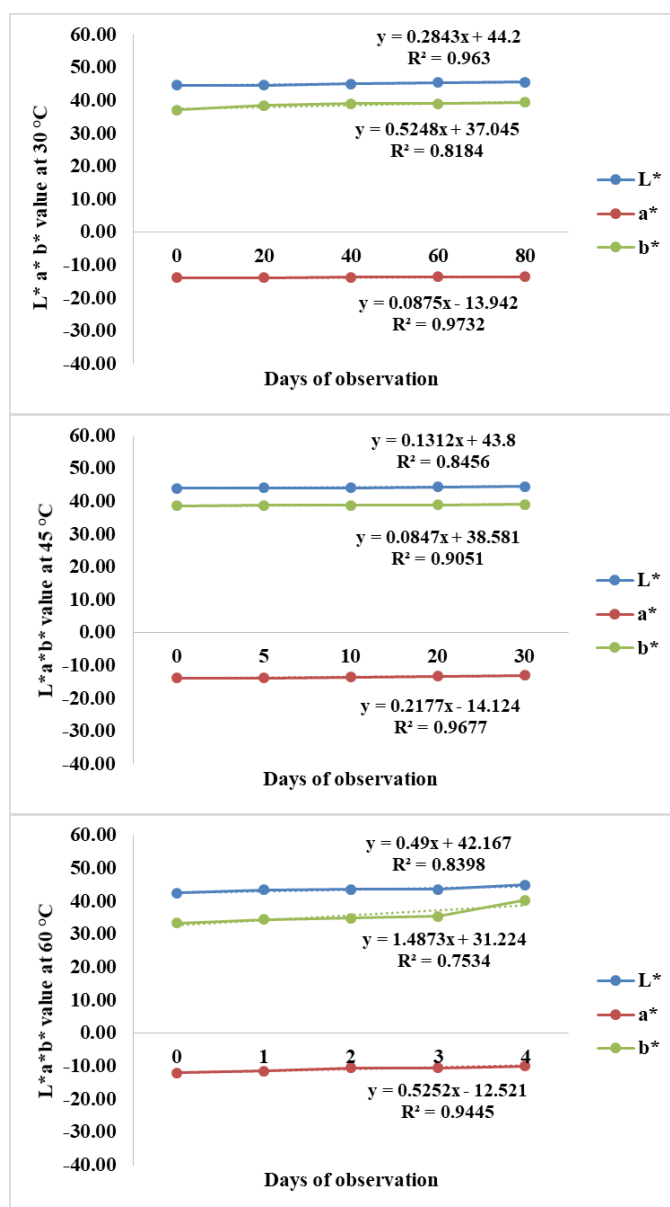


Figure 4. L* (luminosity), a* (redness), and b* (yellowness) value of encapsulated thylakoid of suji leaves (*Dracaena angustifolia* Roxb.) powder at different temperature of storage, 30 °C, 45 °C and 60 °C during the period of storage.



Color Change

The degradation of pigment, by means of color change, was also observed by using ColorFlex. Figure 4 represents the slight increase of lightness (L^*), redness (a^*), and yellowness (b^*) during storage in which the noticeable change can be seen at 60 °C, shown through its gradient value. This results show that the lightness of microcapsules become dull with time, followed by the decrease of greenness and the increase of yellowness as chlorophylls were degraded into pheophytin and other derivatives pigments. Chlorophyll is closely related to the green color and its disruption could be affected by temperature of storage. The green color of the microcapsules which is composed of Chl *a* (responsible for blue-green color) and Chl *b* (responsible for yellow-green color) decreased as the decrease of ratio of Chl *a* to Chl *b*, following the susceptibility of Chl *a* to thermal treatment. This impacts on the gradually increase of yellow color intensity.

In relation to the total color difference (ΔE), the ΔE value of microcapsules stored at 30 °C for 80 d was in the range of 0.74 to 2.58, while at 45 °C for 30 d was 0.12 to 1.04. In addition, for the microcapsules stored at 60 °C for 4 d, the ΔE value ranged from 1.64 to 7.69. This is in accordance to the study of Lemus-Mondaca *et al.* [29] which heated the stevia leaves using convective drying, vacuum drying and infrared drying at 60 °C and resulted in the ΔE value ranging from 8.93 to 9.86. Value of total color difference 2 was provided by microcapsules stored at 30 °C for 40 d which means that vivid green powder was able to preserve its visual color without any obvious change to an untrained eye up to 40 d of storage at 30 °C. Therefore, it could be a promising ingredient to replace the synthetic colorants as it could show its greenness for more than 1 mo at quite high temperature (30 °C) of storage for pigments.

CONCLUSION

Encapsulation of thylakoid of suji leaves which contained pigment protein complex predominated by chlorophyll was able to protect the pigments against external environment which in turn prolonged the shelf life at least for 40 d of storage. Total chlorophyll (TC) was decreased with time with the highest decrease occurred at 60 °C for 4 d of storage, while the lowest one was at 30 °C for 80 d of storage. The dominant pigment found in both fresh and heated microcapsules was from chlorophyll group which was Chl *a* although in the highest temperature of storage the area was lower and the derivative pigments such as Pheo *a* was found. Those pigments were known to have antioxidant activity which is useful for health. This study could be a part of encapsulation method which is not only focusing on the use of encapsulating agent but also the natural component of derived raw material which is thylakoid.

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Abstrak

Suji (*Dracaena angustifolia* Roxb.) merupakan salah satu tanaman khas Indonesia yang dapat digunakan sebagai pewarna makanan alami. Kerentanan pigmen alami terhadap pengaruh lingkungan menuntut adanya proteksi untuk memperpanjang umur simpan. Teknologi enkapsulasi telah banyak diterapkan dalam proses perpanjangan umur simpan beberapa bahan pangan termasuk pewarna alami. Tujuan dari penelitian ini adalah untuk mengobservasi metode isolasi dan enkapsulasi tilakoid, dan untuk menginvestigasi stabilitas dan karakteristik dari tilakoid daun suji yang dienkapsulasi dengan menggunakan maltodekstrin selama penyimpanan dalam keadaan gelap pada suhu 30 °C, 45 °C, and 60 °C. Degradasi pada pigmen terenkapsulasi diidentifikasi melalui analisa kromametrik dimana berdasarkan hasil yang diperoleh terjadi peningkatan nilai L* (kecerahan), a* (kemerahan), dan b* (kekuningan). Selain itu, juga terjadi penurunan nilai klorofil total (TC) selama penyimpanan yang ditentukan dengan menggunakan spektrofotometer. Melalui analisa kromatografi dikonfirmasi bahwa terdapat empat puncak utama pada serbuk enkapsulat tilakoid segar dan lima puncak utama pada serbuk enkapsulat tilakoid yang disimpan pada suhu 60 °C dengan Chl a sebagai pigmen dominan pada kedua serbuk. Warna hijau dari serbuk pewarna dapat dipertahankan tanpa dideteksi adanya perubahan pada mata tak terlatih hingga 40 hari penyimpanan pada suhu 30 °C. Oleh karena itu, pewarna makanan hijau alami dari daun suji tersebut dapat dikembangkan lebih lanjut dan diaplikasikan untuk mensubstitusi pewarna sintetik.

Kata kunci: *Dracaena angustifolia* Roxb., enkapsulasi, pewarna makanan alami, stabilitas