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Efficiency and Thermal Stability of Encapsulated Anthocyanins from Red Dragon Fruit (*Hylocereus polyrhizus* (Weber) Britton & Rose) using Microwave-assisted Technique

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Anthocyanins are one of the commonly used natural colorants for beverages, confectionary, fruit preparation and ice cream. Strong antioxidant activity of these anthocyanins has attracted great interest to the food industry. The instability of anthocyanins through the factors such as light, pH, temperature and oxygen has given problem during processing and storage of these compounds. One of the approaches to overcome this problem is by encapsulating the material using wall material. This study was conducted to investigate the efficiency of encapsulation of anthocyanins from red dragon fruit (*Hylocereus polyrhizus* (Weber) Britton & Rose) using microwave-assisted technique with different drying times and thermal stability of the encapsulated anthocyanins. Encapsulated anthocyanins were produced in form of powder using maltodextrin as the wall material. The encapsulation drying time were varied from 1 min to 3 min with fixed power, 330W. The encapsulated anthocyanins were analyzed in effect of thermal heating (60°C and 80°C). The results indicated that, at different encapsulation drying time, 2 min capsule showed the highest yield of encapsulation where 3 min capsule showed the highest encapsulation efficiency followed by 2 min capsule with 4% differences. From this study the encapsulation at 2 min drying time showed the most feasible encapsulation process. Thermal study at 60°C and 80°C showed that anthocyanins degraded faster at higher temperature, 80°C for all capsule types.

1. Introduction

Natural colorants are recognized as organic products that have gained a growing interest among health conscious consumers and researchers (Griffiths, 2005). It has high potential as an alternative to synthetic dyes in food, pharmaceutical and cosmetics industry. One of the popular natural colorants that are used in food industry is anthocyanins. Anthocyanins are water soluble phenolic compound that responsible for wide range of color such as orange, red, blue and purple colors in most parts of a plant. Deep purple color of red dragon fruit pulp signifies high potential of anthocyanins source. However, the introduction of anthocyanins into food or medical fields has proven to be a major technological challenge since these compounds have low stability to environmental conditions during processing and storage (Santos and Meireles, 2010).
Dragon fruit or also known as *Hylocereus polyrhizus* comes in three types that are *Hylocereus undatus* (red-skinned fruit with white flesh), *Hylocereus polyrhizus* (Weber) Britton & Rose or *Hylocereus costaricensis* (red-skinned fruit with red flesh) and *Hylocereus megalanthus* (yellow-skinned fruit with white flesh). Studies have shown that a mature dragon fruit contains considerable amount of total soluble solids, rich in organic acids (Stintzing et al., 2003), protein (Le Bellec et al., 2006) and other minerals like potassium, magnesium, calcium and vitamin C. Vaillant et al. (2005) established that the dragon fruit exhibited high antiradical activities with the presence of other phenolic compounds but characterization has yet to be reported.

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1.1 Encapsulation
Encapsulation facilitates light and heat-labile molecules to maintain their stability and improve their shelf lives and activity (Santos and Meireles, 2010). It protects the food components in powder form from oxygen, humidity, light, avoids caking phenomena during storage and transport, to improve appearance, taste or odors of product and easily handled in solid (Saleh and Guigon, 2007). The types of wall materials and the process technologies used can influence the morphological shape of microcapsule in a product (Fang and Bhandari, 2010). Maltodextrins, could dry fruit juices into powder form, thus reduce stickiness and agglomeration problems during storage (Silva et al., 2006; Gabas et al., 2007).

1.2 Microwave technique
Microwave is a source of heat that has the ability to rapidly heat material, more uniform and energy efficient. The advantages of using microwave drying include shorter drying time, low cost, improved product quality and flexibility in producing a variety of dried product (Hangi and Amanifard, 2008). The technique has been upgraded by combining the microwave with forced air or vacuum since microwaves alone cannot fully complete a drying process, so as to improve the process efficiency and complete the drying (Hangi and Amanifard, 2008).

1.3 Thermal stability of anthocyanins
Most reactions show the rate of anthocyanins degradation in natural and model systems was affected by processing and storage temperatures (Jackman et al*.,* 1987). The thermal stability of anthocyanins differs with their structure, pH, the presence of oxygen and interactions with other components in the systems (Jackman and Smith, 1996). When subjected to heating process, degradation occurs mainly caused by oxidation, cleavage of covalent bonds or superior oxidation reactions.

1.4 Objective
This study was conducted to investigate the efficiency of red dragon fruit anthocyanins encapsulation using microwave-assisted technique at different drying times and the thermal stability of encapsulated anthocyanins.

2. Experimental procedures

2.1 Extraction of anthocyanins
This method followed Herbach et al. (2006) with slight modifications. For extraction, the fruits were halved and peeled manually. The flesh was squeezed through a commercial sieve and the resulting juice was filtered using miracloth. The pectin substances in the filtered juice were eliminated by precipitation with water at a ratio of 2 mL water to 1 mL red dragon fruit juice. The filtrate was centrifuged at 10,000 rpm for 10 minutes to remove precipitate. The supernatant was stored at 4°C for next procedure.

2.2 Encapsulation of anthocyanins
The encapsulation process used maltodextrin as wall material. Maltodextrin was mixed with concentrated red dragon fruit anthocyanins at ratio 1:10 (v/v) and stirred until homogenized using homogenizer for 20 min. The mixture was put in a petri dish for drying process in a domestic microwave oven. For drying process, 1 variable was used that is time of drying, with fixed heating power. In this study only 30%P was used from 1100W of power. For the time of heating, 5 different drying time were used: 1 min, 1.5 min, 2 min, 2.5 min and 3 min.

2.3 Analysis of encapsulated anthocyanins
To evaluate the effectiveness of the encapsulation, method proposed by Zhang et al. (2007) was used. Effectiveness of encapsulation was evaluated from yield and efficiency of encapsulation. The yield of encapsulation (EY) during microwave-assisted is defined as the ratio of total anthocyanins content in the powder to the anthocyanins content in the extract Eq(1).

$$\%EY = \frac{\text{Total anthocyanin content in the powder}}{\text{Total anthocyanins content in the extract}} \times 100 \quad (1)$$

The efficiency of encapsulation (EE) (%) is defined as the degree of anthocyanins encapsulated in the method Eq(2).

$$\%EE = \frac{(\text{Mtot} - \text{Msurf})}{\text{Mtot}} \times 100 \quad (2)$$

Msurf = amount of anthocyanin on the microcapsule surface
Mtot = total anthocyanin in the product

For the determination of Surface Anthocyanins Microcapsule, 0.1 g of anthocyanins microcapsule sample was washed for 5 min in 45 mL anhydrous ethanol and then filtered. After 5 min, 1 mL of distilled water was added to the filtrate and the anthocyanins content was determined.
For determination of the Total Amount of Anthocyanins Microcapsule, 0.1 g of anthocyanins microcapsules was mixed with 1 mL distilled water and grounded to degrade the microcapsule membrane. The sample was extracted for 5 min after addition of 9 mL of anhydrous ethanol and then filtered.

2.4 Thermal stability of encapsulated anthocyanins

Kirca et al. (2006) has described thermal stability study. Degradation was studied at two different temperatures; 60°C and 80°C. For food purpose, it was evaluated at pH 3 solution as most of foods are acidic.

3. Results and discussion

3.1 Encapsulation of anthocyanins

The encapsulation process of red dragon fruit anthocyanins was done by microwave assisted technique at five different drying times to find the outcome of using the different time as well as to identify the most efficient and suitable condition. Products of encapsulated anthocyanins are illustrated in Figure 1 showing distinctive colors at different drying times. Table 1 shows color parameter of the powders.

Figure 1: Encapsulated anthocyanins powder at 5 different drying times.

From this study, lightness of the powder increased as the drying time increased, except for the 3 min drying. The a* value that indicate redness of color also increased as the drying time increased except for the 3 min drying time. This is because the 3 min capsule has reddish brown color that might be caused by over-heating and slightly burnt. The Chroma value also increased as the drying time increased for all drying time. The result shows that drying time can change the powder color which is one of the important factors for natural colorant application.

Table 1: Color parameters of the encapsulated anthocyanins powder

Capsule	L*	a*	b*	C*	H^0
1 min	36.80 ± 0.14	6.60 ± 0.14	5.50 ± 0.14	8.59 ± 0.02	0.69 ± 0.02
1.5 min	38.30 ± 0.57	7.20 ± 0.14	5.35 ± 0.07	8.97 ± 0.07	0.63 ± 0.01
2 min	42.25 ± 0.70	8.70 ± 0.14	5.30 ± 0.00	10.18 ± 0.12	0.54 ± 0.01
2.5 min	43.55 ± 0.77	9.65 ± 0.63	7.40 ± 0.14	12.16 ± 0.59	0.65 ± 0.02
3 min	38.65 ± 0.35	4.60 ± 0.28	12.50 ± 0.14	13.31 ± 0.23	1.21 ± 0.02

Figure 2 shows total anthocyanins content (TAC) for each capsule type. It shows that capsule powder of 2 min drying time has the highest TAC which was 0.52 ± 0.02 mg/L followed by 3 min drying time 0.29±0.03 mg/L and for 1.5 min, 2.5 min and 1 min the content were 0.21 ± 0.0 mg/L, 0.19 ± 0.01mg/L and 0.05 ± 0.01 mg/L, respectively. From this study, 2 min was the optimum time for the heating at 330W since shorter drying time may not enough for the wall material to encapsulate the core and the longer dying time may degrade the anthocyanins content in the capsule.
Efficiency of encapsulation (EE) of 2 min and 3 min drying time were 71.67% and 75%, respectively. The other capsules resulted in negative value of encapsulation efficiency, that are -460%, -34.61% and -58.33% for 1 min, 1.5 min and 2.5 min capsule, respectively. These negative values signified that the anthocyanins content at the surface of capsule was much higher than anthocyanin content in the core of capsule. The reason of this to happen might because of the short dying time at 1 min and 1.5 min where the heat supplied was not enough for the wall material to coat the extract perfectly, thus resulted in the extract mixed together at the wall material surface.

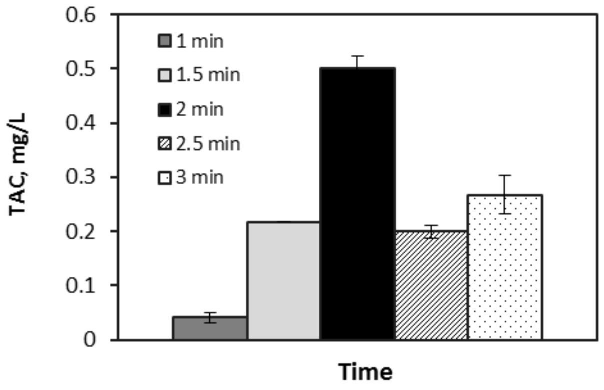

Figure 2: Total anthocyanins content (TAC) at different drying time.

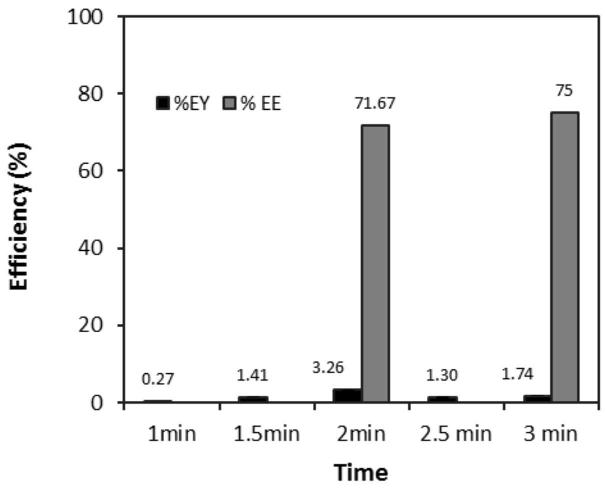

Figure 3: Efficiency of encapsulation, %EE and yield of encapsulation %EY at different drying times.

3.2 Thermal stability of encapsulated anthocyanins

Anthocyanin stability can be affected by temperature. Thermal degradation of encapsulated anthocyanins was studied at two different temperatures (60°C and 80°C) for all type of capsule (1 to 3 min). Monomeric anthocyanins content were calculated for every 15 min of heating to investigate the degradation rate. The values were then compared to initial value, giving in % of total anthocyanins content left in the solution.

Figure 4 (a) shows percent of anthocyanins content from initial value after heating at 60°C while Figure 4 (b) shows percent of anthocyanins content after heating at 80°C. Both of the heating temperature shows degradation of anthocyanins for all capsule types but it is shown that anthocyanins degrade faster at 80°C. It is supported by a finding which also said the degradation rate of anthocyanins increases during processing and storage as the temperature rises (Alighourchi and Barzegar, 2008). When the temperature increased, it would destruct the wall material from the core material and easily degrade at rapid rate. Markakis et al. (1957) suggested that the initial mechanism degradation of anthocyanins involve formation of the colourless carbinol pseudobase and thus opening of the pyrylium ring to form the chalcone.

These results corresponded to the point of view that lower temperature treatment would extend the shelf life of solution and stability of anthocyanin. From this study, we also found that the degradation of antocyanins is different for all types of capsule. All capsule types show certain amount of anthocyanins at 60°C after 60 min heating except 2.5 min capsule where the percent of anthocyanins content is 0% after the 60 min heating. However, the content of anthocyanins after 60 min heating at 80°C for all types of capsule degraded to 0% except 2 min capsule. This result indicated that 2 min capsule has the highest shelf life than others.

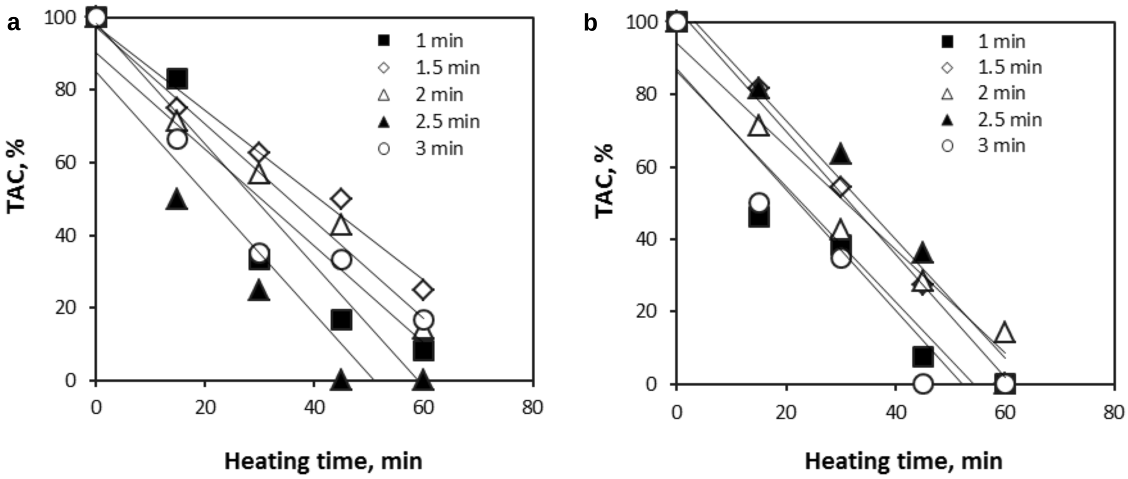

Figure 4: Degradation of anthocyanins during heating at (a) 60°C; (b) 80°C

4. Conclusion

The findings of the present study emphasize the promising feasibility of encapsulated anthocyanins by using microwave drying which used different drying time. For the different encapsulation drying time, 2 min capsule showed the highest yield of encapsulation where 3 min capsule showed the highest encapsulation efficiency followed by 2 min capsule with 4% differences. Result for 2 min drying showed the most feasible encapsulation in this study. Thermal study at 60°C and 80°C showed that anthocyanins degraded faster at higher temperature, 80°C for all capsule types.

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