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# อายุการเก็บรักษาผลละมุดสีดา

## Storage Life and Shelf Life of *Madhuca esculenta* (Sapotaceae) Fruit

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**Abstract**

Effect of storage temperature (5, 10, 15, 20, and 25ºC; 85-90% RH) on ripening of *Madhuca esculenta* fruit (small sapodilla) was investigated. Fruit were placed in corrugated cardboard boxes and stored at 5, 10, 15, 20 and 25ºC. The fruit held at 15ºC riped (ready to eat) after 9-12 days, those held at 20ºC riped after 4 days, and fruit held at 25ºC riped after 3 days. While the fruit held for 4 days at 5ºC or 10ºC, and transferred to 20ºC, the fruit riped within 3-4 days, and fruit stored 7 days at these temperatures and transferred to 20ºC, the fruit riped within 3-5 days. Fruit that stored at 5ºC or 10ºC for 2 weeks did not ripen and rotted after such transfer. Sucrose levels in the fruit flesh were highest when held at 20°C (determined on day 2 and 4) or at 15°C for 4 days and transferred to 20°C for 2 days. Ethylene production showed a maximum which was found earlier at 25ºC than at 10ºC. No detectable ethylene production was found in fruit held at 5ºC or 10ºC. Exposure of mature fruit (bright-orange peel) to ethylene (1 μL $L^{-1}$ at 25ºC for 24 h) did not affect ripening, but in younger fruit (brown-orange peel) it hastened softening, and prevented after treat with 1-MCP. 1-MCP treatment delayed the shelf life of brown-orange fruit from 4 to 8-9 days. Respiration also showed a climacteric peak. It is concluded that *Madhuca esculenta* fruit is climacteric and shows chilling injury when stored for 7 days or longer at ≤ 10ºC. Optimum storage temperature was about 15ºC.

**Keywords**: *Madhuca esculenta,* chilling injury, ethylene

**บทคัดย่อ**

การศึกษาการสุกของละมุดสีดาเก็บรักษา ที่อุณหภูมิ 5, 10, 15, 20 และ 25 องศาเซลเซียส ความชื้นสัมพัทธ์ 85-90% พบว่า ผลละมุดสีดา ที่อุณหภูมิ 15 องศาเซลเซียส สุกในระยะเวลา 9-12 วัน และสุกภายใน 4 และ 3 วัน ที่อุณหภูมิ 20 และ 25 องศาเซลเซียส ตามลำดับ ส่วนผลที่เก็บรักษาที่ 5 หรือ 10 องศาเซลเซียส นาน 4 วัน แล้วย้ายไปที่อุณหภูมิ 20 องศาเซลเซียส สามารถสุกได้ในเวลา 3-4 วัน ในขณะที่ผลที่เก็บนานขึ้นเป็น 7 วันแล้วย้ายไปที่ 20 องศาเซลเซียส สามารถสุกได้ในเวลา 3-5 วัน ส่วนผลที่เก็บรักษาที่อุณหภูมิ 5 หรือ 10 องศาเซลเซียส นาน 2 สัปดาห์ ไม่สุก และเกิดเน่าเสียเมื่อย้ายมาที่อุณหภูมิ 20 องศาเซลเซียส ปริมาณน้ำตาลซูโครสของผลเพิ่มขึ้นเมื่อเก็บรักษาที่ 20 องศาเซลเซียส นาน 4 วัน หรือ ที่ 15 องศาเซลเซียส นาน 4 วัน แล้วย้ายไปที่ 20 องศาเซลเซียสอีก 2 วัน พบการผลิตเอทิลีนของผลละมุดสีดาที่ 25 องศาเซลเซียส ก่อนผลที่ 10 องศาเซลเซียส และไม่พบการผลิตเอทิลีนในผลที่เก็บรักษา ที่ 5 และ 10 องศาเซลเซียส การให้ เอทิลีน 1 μL $L^{-1}$ 24 ชม.ที่อุณหภูมิ 25 องศาเซลเซียส ไม่มีผลต่อการสุกของผลที่แก่จัด (สีส้มสด) แต่มีผลต่อผลอ่อนกว่า (สีน้ำตาล-ส้ม) ที่เร่งทำให้ผลนิ่ม ส่วนการใช้ 1-MCP มีผลกับผลที่อายุน้อย (สีน้ำตาล-ส้ม) โดยยืดอายุเก็บรักษาจาก 4 วัน เป็น 8-9 วัน จากอัตราการหายใจที่แสดง climacteric peak สามารถสรุปได้ว่า ละมุดสีดาเป็น ผลไม้พวก climacteric และแสดงอาการสะท้านหนาว เมื่อเก็บรักษาที่อุณหภูมิต่ำกว่า 10 องศาเซลเซียส นานมากกว่า 7 วัน และอุณหภูมิที่เหมาะสมในการเก็บรักษาผลละมุดสีดา คือ 15 องศาเซลเซียส

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## Introduction

No data are apparently available on postharvest handling of *Madhuca esculenta* fruit. The species is in the Sapotaceae, has been described by Fletcher (1937). The genus name is said to derive from the Sanskrit *madhu* which means honey. The fruit seems to have no English name yet. We called it 'small sapodilla'. *Madhuca esculenta* fruit is a berry which at full ripeness (ready to eat; dark brown peel colour) has an oval shape. On the tree the smooth-skinned fruit turns from green to bright orange. Intermediate stages are greenish brown and brown orange. Fruit can be picked at the brown-orange and orange stages. After harvest (and on the tree) the peel changes from (brown-) orange to light brown and then to dark brown. The fruit is fleshy, that are light brown to brown. The dark-brown pulp of mature fruit has a mild aroma. The objectives of this study were to investigate the optimum storage temperature of *Madhuca esculenta* fruit, testing eating quality, ethylene production and respiration. We also investigated the effect of exogenous ethylene and 1-MCP (an inhibitor of ethylene perception) on fruit ripening.

## Materials and Methods

*1. Quality of fruit stored at various temperatures*

Mature fruit of *Madhuca esculenta* F.R. Fletcher were harvested in Samutprakan province, Thailand, that had a bright orange skin and hard flesh. Fruit were stored at 5, 10, 15, 20 or 25ºC, at 85-90% RH, either continuously held at these temperatures or were transferred to 20ºC for ripening. Fruit quality was assessed daily. Shelf life was defined as the time to turning brown of the skin. Changes in peel colour were determined. Eating quality was assessed in dark brown fruit. The total sugars, reducing sugars and sucrose, were assessed on day 4 and 7 during storage at 5, 10, 15 and 20ºC and also determined 2 day after transfer to 20ºC. A 2 day interval was also used for fruit remaining at 20ºC.

*2. Ethylene production and respiration rate*

The orange or brown-orange stage, were stored at 5, 10, 15, 20 or 25ºC, for carbon dioxide and ethylene production. Fruit were stored at 15, 10 or 5ºC for 4 or 7 days and then transferred to 20ºC for the investigation of ethylene production and respiration.

*3. Ethylene treatment and 1-MCP treatment*

The greenish-brown stage, the brown-orange stage, or the orange stage were treated with 1 $\mu$L $L^{-1}$ ethylene at 25ºC for 24 h. And the brown-orange were treated with 200 and 500 nL $L^{-1}$ 1-MCP (EthylBloc, Floralife) at 25ºC for 6 h. In the controls, an ethylene scrubber (chalk+ $KMnO_4$) and a carbon dioxide scrubber (calcium oxide) were included in the containers, while in the ethylene treatment or the 1-MCP treatment only the carbon dioxide scrubber was used. After the treatment, fruit were placed at 20°C and determined of fruit colour and sensory quality throughout this experiment.

## Results

*1. Storage and shelf life of fruit held at various temperatures*

Fruit were held at 5, 10, 15, 20 or 25ºC. The peel colour of fruit stored continuously at 15-25ºC changed from orange to dark brown in 85-100% of the fruit surface area. At 15ºC this colour change took place after 9-11 days, compared with 4 and 3 days in fruit held at 20ºC and 25ºC, respectively (Table 1). Fruit placed at 5ºC or 10ºC did not exhibit a change in peel colour throughout 28 days of storage period. Colour changes were observed in the fruit that had been held for 4-5 days at 5-10ºC and were then transferred to 20ºC for 3-4 days.

Storage life was defined as the time to a dark brown peel during the period of storage. Shelf life was defined as the time to a dark brown peel in fruit taken out of storage and placed at 20ºC. The above-described periods of the change to dark brown peel therefore reflect storage life and shelf life (Table 1).

Orange fruit was inedible. Dark brown fruit was considerably softer and could therefore be eaten. The eating quality of dark brown fruit was acceptable, irrespective of the storage temperature. The eating quality of dark brown fruit was also similar to the other treatments after 4 days of storage at 5 or 10ºC and subsequent transferred to 20ºC. The same result was found after storage for 7 days and transferred to 20ºC.

In fruit held at 20°C the total sugars and reducing sugars decreased during 4 days of storage, while the sucrose increased. In fruit held at lower temperatures (15, 10 and 5°C) for 7 days the concentrations of total sugars, reducing sugars, and sucrose did not change. Fruit that was held at 15°C for 4 days and was then transferred to 20°C for 2 days showed an increase in sucrose and a decrease in reducing sugars. Fruit that was held at 15°C for 7 days and was then transferred to 20°C for 2 days, exhibited a small increase in sucrose and a decrease in both total sugars and reducing sugars. A similar increase in sucrose concentration was also found in fruit that was held 10°C for 4 or 7 days and was then transferred to 20°C for 2 days. A small increase in sucrose concentration was found in fruit held at 5°C, between day 4 and 7, but the concentration did not increase after transfer to 20°C (data not shown).

*2. Ethylene production and Respiration*

In brown- orange fruit held at 25ºC the maximum ethylene production and a peak of respiration (Fig. 1) was found on day 2. Such a maximum occurred on day 3 and day 6 in fruit held at 20ºC or 15ºC, respectively. Ethylene production and respiration were very low in fruit held at 10ºC or 5ºC. A large increase was observed after transfer on day 4 from 5 to 20°C. In fruit that were orange, the maximum ethylene production and respiration at 25ºC and 20ºC was found one day earlier than in brown-orange fruit. The rates after transferred from at 10ºC or 5ºC to 20°C did not show the large increase of respiration in orange fruit (data not shown).

*3. Effects of exogenous ethylene*

Ethylene treatment was carried out at 25ºC, using fruit at three developmental stages. The peel of the controls and the ethylene-treated fruit turned to dark brown (Table 2). The colour change in fruit that was orange at the onset of ethylene did not differ from that in non-ethylene treated controls. In younger fruit the change to dark brown was accelerated by ethylene (Table 2**)**. The similar was found on the colour assessments of L*, a* and b* values (data not shown).

*4. Effects of 1-MCP*

1-MCP treatment was carried out at 25ºC for 6 h, using brown-orange fruit before stored at 20 ºC. The peel of the controls changed to dark brown in 85-100% of the fruit surface area after 4-5 days, compared with 6-8 days and 8-9 days in fruit treated with 200 and 500 nanolitre $L^{-1}$, respectively (Table 3).

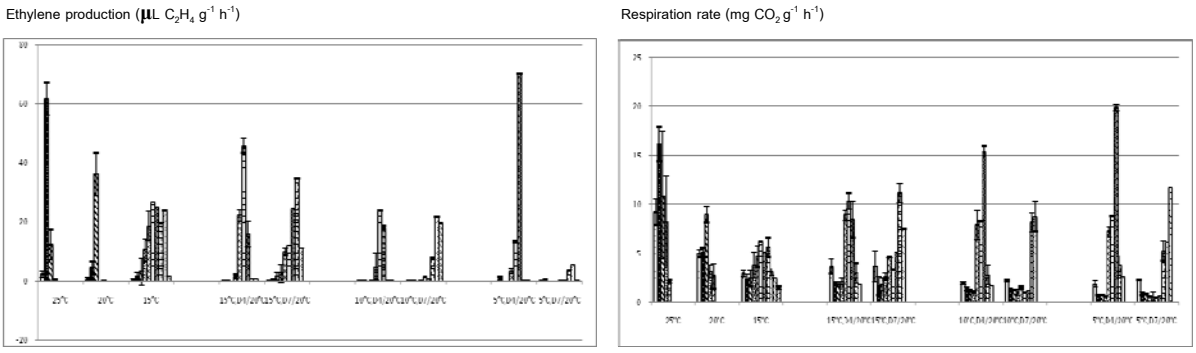


**Fig.1** Ethylene production and respiration rate of *Madhuca esculenta* brown-orange fruit.

**Table 1.** Storage and shelf life of *Madhuca esculenta* fruit, were stored continuously for 12 days at various temperatures, or stored for 4 or 7 days at 5, 10 or 15ºC and then transferred to 20ºC.

| Treatment | | Storage life (d) |
|---|---|---|
| 25ºC continuous | Exp. 1. | 2.9 ± 0.7 d |
| | Exp. 2. | 2.7 ± 0.6 d |
| 20ºC continuous | Exp. 1. | 4.1 ± 0.3 c |
| | Exp. 2. | 3.9 ± 0.5 c |
| 15ºC continuous | Exp. 1. | 8.5 ± 1.6 b |
| | Exp. 2. | 12.0 ± 1.8 a |
| 10ºC continuous | | -* |
| 5ºC continuous | | -* |

| Treatment | Shelf life (d) | Storage life + shelf life (d) |
|---|---|---|
| 15ºC for 4 d, then to 20ºC | 3.1 ± 0.3 c | 7.1 ± 0.3 e |
| for 7 d, then to 20ºC | 2.7 ± 0.5 d | 10.0 ± 0.5 c |
| 10ºC for 4 d, then to 20ºC | 3.8 ± 0.4 b | 7.8 ± 0.4 d |
| for 7 d, then to 20ºC | 4.1 ± 1.0 b | 11.1 ± 1.0 b |
| 5ºC for 4 d, then to 20ºC | 4.1 ± 0.8 b | 8.1 ± 0.8 d |
| for 7 d, then to 20ºC | 4.9 ± 0.7 a | 11.9 ± 0.7 a |

**Table 2.** Effect of fruit stage on peel colour at 20ºC, after treatment with 1 µL L-1 ethylene at 25ºC for 24 h.

| Fruit colour at onset of experiment | Color change (%) on day 2 | |
|---|---|---|
| | Control | Ethylene |
| Greenish-brown | 56.6 ± 9.5 b | 93.9 ± 6.3 a |
| Brown-orange | 60.0 ± 8.6 b | 88.1 ± 7.5 a |
| Orange | 90.6 ± 11.5 a | 95.0 ± 7.8 a |

**Table 3.** Effect of brown-orange fruit on shelf life at 20ºC, after treatment with 0, 200 and 500 nL L-1 1- MCP at 25ºC for 6 h.

| Treatment | Shelf life (d) | |
|---|---|---|
| | Exp. 1. | Exp. 2. |
| 0 nL $L^{-1}$ 1-MCP | 4.0 ± 0.0 c | 5.2 ± 0.5 b |
| 200 nL $L^{-1}$ 1- MCP | 6.2 ±1.2 b | 8.5 ± 2.3 a |
| 500 nL $L^{-1}$ 1- MCP | 8.0 ± 0.7 a | 9.4 ± 2.4 a |

## Discussion

The optimum storage temperature for *Madhuca esculenta* fruit was 15ºC. This is close to data of Kader (2005) regarding sapodilla fruit (*Manilkara sapota*) and similar to data on mamey sapote (Diaz-Perez *et al*., 2003). Interestingly, our data showed that fruit could be held at 5ºC or 10ºC for 4-7 days before transfer to 20ºC. This did not negatively affect fruit ripening. This is similar to the data reported on sapodilla fruit (Morton, 1987). Our data support the contention of others (Balerdi and Crane, 2005; Kader, 2005) that although some fruit are chilling-sensitive, a short period at low temperature often does not affect fruit quality.

The maximum total postharvest life (storage life plus shelf life) of *Madhuca esculenta* fruit was about 12 days, which was obtained by holding for 7 days at 5°C, then transferred to 20ºC. Similar long postharvest lives were obtained after holding at 10°C or 15°C for 7 days and transferred to 20°C. Fruit held continuously at 15ºC had a postharvest life of 9-11 days, which is twice longer than at 25°C.

The fruit showed both peaks of respiration and ethylene production, hence was climacteric. Exogenous ethylene induced a more rapid change in colour but was no longer effective in fruit that was already orange. These data are similar to sapodilla fruit (*Manilkara sapota*) and mamey sapote fruit (*Pouteria sapota*)

The younger of brown-orange fruit showed that 1-MCP, could delay the colour change compared with control fruit. The data support the contention of sapodilla fruit and mamey sapote fruit.

Concentrations of reducing sugars, mainly glucose and fructose, were much higher than those of sucrose. This is similar to many other fruit including sapote (Pawar *et al*., 2011). By contrast, sucrose levels were higher than reducing sugars in mamey sapote (Alia-Tejacal *et al*., 2007).

## Conclusion

It is concluded that *Madhuca esculenta* fruit has an optimum continuous storage temperature of about 15ºC. Total postharvest life showed a maximum after 7 days of storage at 10°C or 5°C and subsequent transferred to 20°C. Chilling injury was found in fruit stored for 7 days or longer at $\leq$ 10ºC. The fruit is climacteric and sensitive to exogenous ethylene.

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