Postharvest Behavior during Storage of Young Coconut (*Cocos nucifera* L.) at Different Temperatures

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Abstract

Trimmed young coconuts wrapped with PVC film have a short storage life. Current commercial shipments are carried out at 3-6°C without visual chilling symptoms. Experiments were conducted to study chemical composition and postharvest features of intact and trimmed fruit wrapped with PVC film and stored at 4 and 25°C. After 3 weeks at 25°C, coconut water had a slight off-flavor score while at 4°C a strong off-flavor score was observed. Similar findings were found in the coconut kernel but the scores were higher. Trimmed fruit had a much higher respiration and ethylene production rate than intact fruit. At 4°C, the coconut water had about 100-300 nl L^{-1} dissolved O_2, but at 25°C, O_2 could not be detected. TBA reactive compounds in coconut water at 25°C increased slightly during storage, while at 4°C it was about 50% higher than 25°C after 2 weeks of storage. TBA reactive compounds in the coconut kernel were 3 times higher than in coconut water, but there was no difference between the two storage temperatures. Electrical conductivity in coconut water at 4 and 25°C was similar, while the electrolyte leakage from the kernel at 4°C was 20% higher than at 25°C. The data suggested that 4°C was a suboptimal storage temperature for young coconut.

INTRODUCTION

Young coconuts are typically harvested 6 to 9 months after full bloom, when the fruit approaches full size (Paull and Ketsa, 2004). The fruit is typically trimmed or polished to reduce transportation cost, and to improve presentation. Immediately after trimming or polishing, the fruit is dipped in sodium metabisulfite solution to prevent browning and mold growth on the surface. The use of ≤5 min dipping in ≤5% sodium metabisulfite is recommended to avoid chemical residue in the edible portion of trimmed young coconut (Mohpraman and Siriphanich, 2011). This procedure is followed by immediate wrapping in plastic film and a cooling process (Tongdee et al., 1991).

Maciel et al. (1992) reported that storage at 12°C for five weeks caused no damage to intact young coconut. However, Wijeratnam et al. (2006) showed that young coconut stored at 13.5°C or lower developed chilling symptoms such as skin browning. Consignado et al. (1976) reported that fruit stored at 17°C was more acceptable than that at 0°C, but lost more water and deteriorated faster. In commercial applications, trimmed coconuts are held at 3-6°C during the 3-4 weeks of sea transport (Paull and Ketsa, 2004). Their storage life ends with the occurrence of mold growth on the trimmed surface and/or off-flavor, limiting their marketing (Siriphanich et al., 2011).

Although no chilling symptom on the trimmed coconut was reported, holding this tropical fruit at 3-6°C could potentially lead to chilling injury which might not be visually observed but resulting in off-flavor that could limit storage life and eating quality. This study was conducted to identify the biochemical changes in trimmed young coconut during storage at low temperature that lead to off-flavor in young coconut.

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MATERIALS AND METHODS

Plant Materials

Young coconut cultivar 'NamHom' (an aromatic cultivar), 6.5 months old after inflorescence full bloom (AFB) were obtained from the university orchard, on campus in Nakhon Pathom, Thailand. Each fruit weighed about 1,200-1,500 g. For the trimmed fruit, the outer green pericarp was sheared off with a long sharp knife. The inner white mesocarp was then finely shaped to form an inverted conical shaped top, a slightly tapered cylindrical body, and a flat base.

Respiration and Ethylene Production

Trimmed fruit were dipped in 3% sodium metabisulfite for 5 min and kept at 25 or at 4±1°C for 7 days. Each fruit was placed in a 5-L container having continuous air flow. Five fruits (replicates) were used for each treatment. Gas samples were taken daily to measure CO_2 and C_2H_4 concentration, using a Shimadzu GC 8A gas chromatograph, Japan, equipped with a Porapak Q column. A thermal conductivity detector and flame ionization detector were used for CO_2 and C_2H_4, respectively. Intact fruit (control) was treated the same way.

Changes in Quality and Chemical Composition

Intact fruit (control) and trimmed fruit wrapped with PVC stretch film (M wrap, BASF USA, 11 µm thickness) were stored at 4 or 25±1°C for 28 days. Five coconut fruits, one fruit as one replicate, were sampled weekly from each treatment. The experiment was conducted twice in a completely randomized design (CRD). Five coconut fruits, one fruit as one replicate, were sampled weekly from each treatment. Means were separated by least significant differences (LSD). Coconut water was drawn from the fruit via the soft eye, using a syringe, for oxygen determination. The main portion of coconut water and the kernel was collected after breaking the fruit open.

1. Sensory Evaluation. Five trained panelists were used to taste the coconut water and kernel and each coconut was rated for their sweet aroma and off-flavor using a 9-points hedonic scale. Where by 1 = no off-flavor, 3 = slight, 5 = moderate, 7 = high and 9 = very high off-flavor.

2. Dissolved Oxygen. Dissolved oxygen concentration in coconut water was determined using the azide titrimetric method AOAC 973.45 (AOAC, 2000). Oxygen concentration in the kernel was determined from gas, drawn from the kernel under water in a glass chamber under low pressure condition, using Shimadzu GC 8A gas chromatograph, Japan, equipped with a molecular sieve 5A column, and a thermal conductivity detector.

3.TBA Reactive Compounds. TBA (thiobarbituric acid) reactive compounds were determined using the modified method of Cakmak and Horst (1991). Ten ml of coconut water or 2 g of the kernel was transferred into a test tube containing 10 ml 10% trichloroacetic acid and shook well. One ml of the mixture sample was transferred into a test tube containing 3 ml of 0.5% thiobarbituric acid, and mixed well. The mixture was boiled at 100°C for 10 min and allowed to cool. Absorbance was determined at 532 and 600 nm. Five ml of trichloroacetic acid at 10% concentration was mixed with 3 ml of 0.5% thiobarbituric acid which was used as a blank.

4. Electrical Conductivity and Electrolyte Leakage. Coconut water was sampled and determined for electrical conductivity according to the method of Gonzalez-Aguilar et al. (2004) using C381 Consort, conductivity meter, Belgium. Samples of coconut kernel were cut into 0.5×0.5×0.5 cm cubes, rinsed with distilled water, then soaked in 0.3 M mannitol for 1 h and measured for electrical conductivity. A duplicate sample of coconut kernel was boiled for 10 min and measured for the electrical conductivity in the same manner. The electrolyte leakage from the kernel was calculated using a formula: % electrolyte leakage = electrical conductivity after boiling/initial electrical conductivity×100.

RESULTS

Respiration and Ethylene Production

Intact young coconut of 6.5 months AFB respired at a low and stable rate of 45-60 mg CO_2 $kg^{-1}h^{-1}$ during storage at 25°C. The rate of the trimmed fruit was almost twice the rate of the intact fruit and was also rather stable. At 4°C, the respiration of trimmed coconut on the first day was 0.6-fold higher than that of the intact fruit. However, after one day of storage, the rate declined and both types of coconut had similar rates of only 5-8 mg CO_2 kg^{-1} h^{-1}.

Ethylene production of the whole intact fruit at 25°C was low at about 50 nl C_2H_4 kg^{-1} h^{-1} at the beginning and slowly increased to about 300 nl C_2H_4 kg^{-1} h^{-1} after 7 days of storage. The ethylene production of the trimmed coconut was 4- to 10-folds higher than the whole fruit throughout the 7 days of storage. At 4°C, ethylene production of the trimmed fruit on the first day was 450 nl C_2H_4 kg^{-1} h^{-1} or 10-fold higher than the intact fruit. On day 2 and 3, the rate was lower to about 120 nl C_2H_4 kg^{-1} h^{-1} but was twice as much as the intact fruit. Later on, the rate declined further and became equal from 4 days on.

Quality and Chemical Compositions of Young Coconut during Storage

1. Sensory Evaluation. During the storage at 25°C, there was no or only a slight off-flavor detected in the coconut water and kernel from both types of fruit during the first weeks. Later on, off-flavor was clearly detected but the scores remained below 3, and not significantly different till the end of 3 weeks storage, when the fruit became spoiled with mold. At 4°C, both types of coconut were free of off-flavor, but after two weeks of storage off-flavor was clearly detected and increased to become significantly higher than that at 25°C (Fig. 1A,B). The off-flavor levels were not significantly different between the trimmed and the intact fruit.

At the beginning and one week after storage at 4°C the sweet aroma score in the coconut water of the intact fruit was moderate (Fig. 1C). With longer storage duration the aroma scores declined, particularly in trimmed fruit. At 25°C the aroma score dropped from the first week of storage to become lower than at 4°C, thereafter. The intact fruit had a slightly higher sweet aroma than the trimmed fruit at both temperatures. For the kernel (Fig. 1D) its aroma was stronger than that observed in the water. The decline in sweet aroma was also found, and was faster at 4 than 25°C. However, statistical analysis showed no significant difference between the storage temperatures and between the intact and trimmed fruit.

2. Oxygen Concentration in the Kernel and Dissolved Oxygen in the Coconut Water. The kernel from both types of coconut at both 4 and 25°C contained about 14% oxygen concentration and remained stable during storage (data not shown). At 25°C, oxygen was not detected in coconut water of intact and trimmed coconut. At 4°C, dissolved oxygen in the whole fruit was rather low at about 0.16 µl L^{-1} on the first day and remained stable during the 4 weeks storage period. For trimmed fruit the oxygen concentrations were similar to that of the intact fruit, except at the end the concentration increased significantly to 0.24 µl L^{-1} (data not shown).

3. TBA Reactive Compounds Content. At 25°C, TBA reactive compounds content in the water of the intact fruit steadily increased from 90 nmol ml^{-1} at the beginning to 350 nmole ml^{-1} after 2 weeks of storage, then remained stable (Fig. 2A). While the trimmed fruit had about 30% lower levels of TBA reactive compounds during the first 2 weeks before increasing to the same level as in the intact fruit at 3 weeks of storage. At 4°C (Fig. 2A), the TBA reactive compound content in both types of coconut were similar and increased to a significantly higher level than that at 25°C. At the end of the 4 weeks of storage, the TBA reactive compound content was higher than 600 nmol ml^{-1}.

At 25°C, the intact fruit was 600 nmol ml^{-1} at the beginning of storage and was stable during the first week, then increased to 1300 and 1600 nmol ml^{-1} after 2 and 3 weeks of storage, respectively (Fig. 2B). The trimmed fruit had similar TBA reactive compounds content to the intact fruit during storage. At 4°C (Fig. 2B), however, the TBA reactive compound content in both types of coconut increased slightly but not significantly higher than at 25°C. At the end of the 4 weeks storage, the TBA reactive compound content at 4°C was about 2,000 nmol ml^{-1}.

4. Electrical Conductivity and Electrolyte Leakage. At 25°C, the electrical conductivity of coconut water from the intact and trimmed fruit was stable at about 5.2 µS during the 3 weeks of storage (Fig. 3A). At 4°C, both types of coconut had a stable electrical conductivity in the coconut water during the first week. After that, the conductivity increased and became significantly higher than at 25°C. The intact fruit had a slightly but not significantly lower conductivity than the trimmed fruit. At 25°C, the electrolyte leakage of the coconut kernel was 43% at the beginning (Fig. 3B). The leakage did not change much during the 3 weeks of storage. At 4°C there was a slight increase during the first two weeks. After that the leakages abruptly increased to 75%, significantly higher than at 25°C and remained there till the end of storage. No difference was detected between the intact and trimmed coconut.

DISCUSSION

The double in respiration rates and the 8-fold increase in ethylene production of young coconut after trimming and stored at 25°C compared to the intact fruit indicated that the trimmed fruits were under stress, due to wounding, similar to that reported in many other minimally processed fruits (Palmer and McGlasson, 1969; Salveit, 2004). Cooling after trimming is essential to minimize the stress as could be seen in the reduction of respiration and ethylene production rate to the same level as intact fruit, and to the maintain the quality of young coconut. Low temperature could also minimize the growth of microorganisms on the cut surface. Bretch (1995) and Myung et al. (2006) reported that wounding in fruit and vegetables could induce the production of volatile compounds that give off-flavor to the produce. In the case of young coconut, the wounding was done to the husk, away from the edible portion, having thick lignified mesocarp (the shell) in between. The induced respiration and ethylene production probably occurred in the husk and their rates were subsided by the low temperature. Hence, off-flavor in the kernel and water of trimmed young coconut should not be the direct result of wounding from the peeling process.

Dissolved oxygen in coconut water was not detected in fruit stored at 25°C by the modified azide method. This finding is in contrast with Wijeratnam et al. (2006), perhaps because of the difference in oxygen detection methodology. However, dissolved oxygen could be detected in our work at 4°C, due to the higher solubility of oxygen at lower temperature (Battino et al., 1983). In addition, the respiration rate at 4°C was lower than at 25°C, less oxygen was consumed by the endosperm, hence more oxygen remained in the coconut water. Although the low oxygen level was found in the water, but anaerobic condition is not likely to occur in the coconut water and contribute to the off-flavor. This is because there were only a few cells in the water at the beginning of the development of the kernel and later on no cell was found in the water (Child, 1974).

Trimming the young coconuts allows oxygen to get into the kernel and water at a higher rate since the barrier (epicarp and mesocarp) has been removed particularly the green epicarp which contains a thick cuticle on the outer surface. Wrapping the trimmed fruit with PVC film resulted in a similar level of dissolved oxygen as in the intact fruit. At ambient conditions the storage life is limited because of the growth of mold on the trimmed surface. Although oxygen concentration in a coconut kernel was about 14% at both temperatures, the dissolved oxygen in cells of the kernel should also be higher at 4°C than at 25°C with the same reason as mentioned on the dissolved oxygen in the coconut water. The level of oxygen indicated that at 25°C the solid endosperm was subjected to a mild anaerobic condition and only a slight off-flavor was detected at this temperature. On the other hand, at low temperature, oxygen should be enough for respiration, but strong off-flavor was detected, indicating that other deteriorative process than anaerobic condition might have occurred.

Our data suggested that the 4°C, or lower storage temperatures used commercially for coconut, was not an optimum one. This is because of the higher off-flavor score, higher electrical conductivity of coconut water and high electrolyte leakage of a coconut kernel that was found in fruit stored at 4°C than at 25°C, indicating that the membrane of the coconut endosperm was damaged as a result of a chilling injury, as shown before in other tropical fruits such as guava (Gonzalez-Aguilar et al., 2004).

Although TBA reactive compounds, the end of product of lipid oxidation, contents in coconut kernel at both storage temperatures were not different, the content in coconut water was higher at 4°C than that at 25°C. This result further indicated that storage at 4°C or lower temperature was suboptimal. In addition to chilling injury, the higher dissolved oxygen at this temperature could additionally oxidize lipids accumulated in the coconut kernel as well as in the water, resulting in more TBA reactive compounds and off-flavor.

To better preserve the fruit, the storage temperature should be raised to avoid chilling stress. However, the growth of microorganisms on the trimmed surface should be effectively prevented. On the other hand, modified atmosphere should also be tested to reduce chilling injury and minimize the occurrence of off-flavor.

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Figures

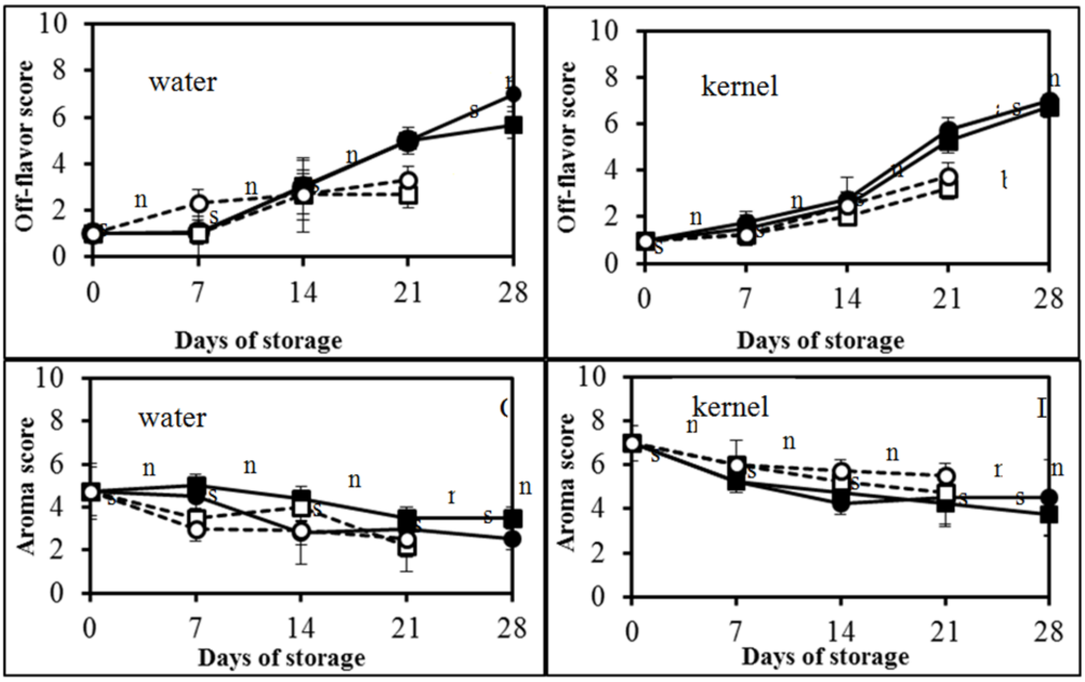

Fig. 1. Off-flavor (A and B) and sweet aroma (C and D) scores of coconut water (A and C) and of coconut kernel (B and D) taken from intact (■), and trimmed (●) fruit stored at at 4°C, and intact (□) and trimmed (○) fruit stored at 25°C for 28 days. Bars on each point represent standard deviation. Different letters indicate significant differences between treatments (P≤0.05), ns = not significant.

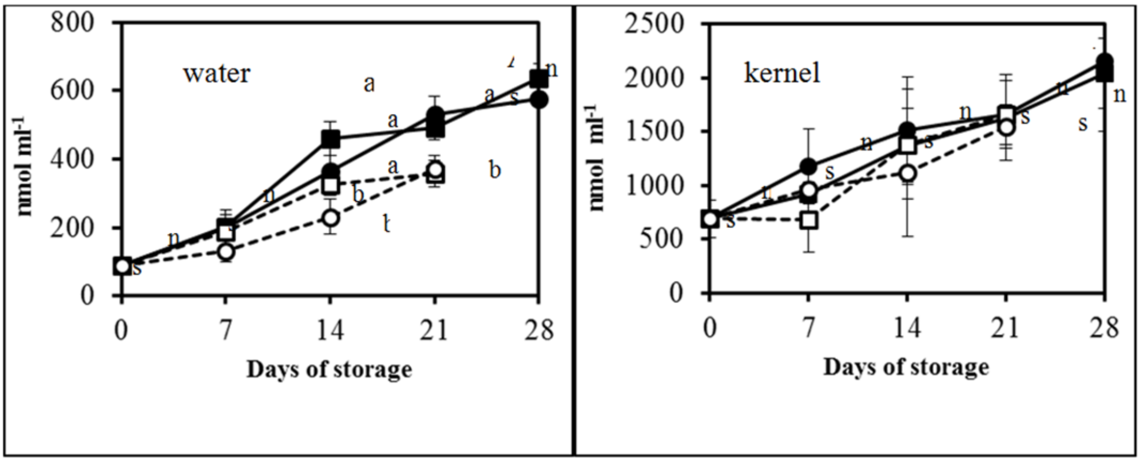

Fig. 2. TBA reactive compound content in coconut water (A) and kernel (B) taken from intact (—■—) and trimmed (—●—) fruit stored at 4°C, and intact (··□··) and trimmed (··○··) fruit stored at 25°C for 28 days. Bars on each point represent standard deviation. Different letters indicate significant differences between treatments ($P \leq 0.05$), ns = not significant.

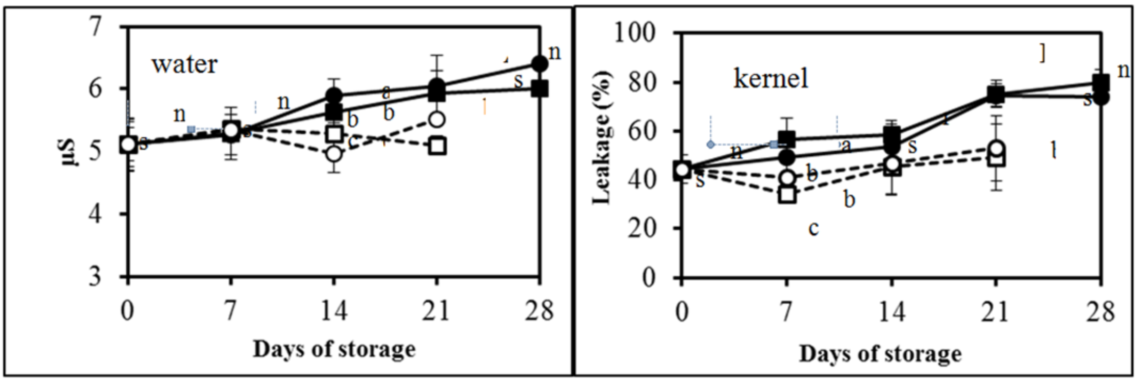

Fig. 3. Electrical conductivity of coconut water (A) and electrolyte leakage of coconut kernel (B) taken from intact (—■—) and trimmed (—●—) fruit stored at 4°C, and intact (··□··) and trimmed (··○··) fruit stored at 25°C for 28 days. Bars on each point represent standard deviation. Different letters indicate significant differences between treatments ($P \leq 0.05$), ns = not significant.