Effect of inpackage temperature and relative humidity on quality of minimally processed limau madu (Citrus reticulate) stored at 25 and 10 °C

[Kesan suhu dan kelembapan relatif dalaman pembungkus terhadap kualiti limau madu (Citrus reticulate) diproses secara minimum dan disimpan pada 25 dan 10 °C]

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Key words: temperature, relative humidity, quality, packing, minimally processed, Citrus reticulate

Abstract

Inpackage temperature and relative humidity of minimally processed limau madu was evaluated to relate to changes in quality during storage at 25 °C and 10 °C. Minimally processed limau madu was packed in the insulated boxes layered with thermal freeze (TF) whereas packing using the corrugated fibre board boxes (CFB) was used as control. At the initial stage, the temperature in the TF packing stored at 25 °C was maintained at 0 °C with relative humidity (RH) 100% for 24 h. The temperature later increased to 3 °C after 36 h, 15 °C after 48 h and 20 °C after 60 h. At all stages, the RH was maintained at 100%. However, temperature in the CFB packing increased from 19–26 °C with RH 55–85% from the beginning of the study until the end of the storage period (3 days). At 10 °C storage, temperature surrounding the TF packing remained at 0 °C for 60 h, then increased to 3 °C after 72 h (day 3) and later maintained at 10 °C until the end of the storage period (day 7). The RH was maintained 100% throughout the storage period. Chemical changes occurred in minimally processed limau madu during storage at 25 and 10 °C, even though no significant differences were observed in the TSS, TTA and acid ascorbic contents with different packing systems and storage temperatures. Similar trend was also observed in the pH of minimally processed limau madu in the different packing systems on day 1 and 3 for samples stored at 25 °C and day 7 for samples stored at 10 °C. Changes in the chemical components of minimally processed limau madu had contributed to the quality and acceptability of the product. Minimally processed limau madu in the TF packing was still good and well accepted even after 2 days stored at 25 °C. However, the taste of minimally processed limau madu in CFB packing was rejected at the end of day 1 even though high TSS and lower percentage of citric acid (TTA value) was determined in the product. The low RH had caused the fruitlets of limau madu to dry. Minimally processed limau madu stored at 10 °C was still accepted until day 7 regardless of the packing systems. However, higher score was obtained for minimally processed limau madu in TF packing compared to those in CFB packing.

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Introduction
Minimally processed (MP) products for both retail and food service application are not common in the market nowadays. The products have been successful in the market because of the value added through its preparation and delivery in ready-to-eat condition with retention in the colour, freshness and flavour. In the next decade, it is perceived that the MP industry will have unprecedented growth.

Temperature has a direct relationship with the freshness and metabolic reactions of a minimally processed product (Brecht 1996). The life span of MP products is influenced by temperature. The integrity of the cold chain system from the supplier to the end-user is the critical component in achieving maximum shelf life, quality and food safety. All biological processes react slowly at low temperature (Zagory 1996) as observed for minimally processed durian, pineapple and jackfruit (Latifah et al. 2000, 2001a, b). Therefore, it is important to maintain temperature at low level so that the quality during storage, transportation and at market display can be retained. Failure to maintain temperature at low level before, during and after processing will result in significant loss of product shelf-life and overall quality (James and Kader 1996).

All minimally processed products are highly perishable and demonstrate rapid postharvest quality degradation over time under ambient storage (Shewfelt 1987). Degradation of quality is primarily due to respiration and ripening process which eventually resulted in subsequent tissue senescence as energy stores are depleted, water loss via transpiration, decay and mould growth and mechanical damage (Marita 1996).

Selection of packaging materials for minimally processed products should be done very carefully. It is a major consideration in the production and marketing of minimally processed products (Zagory 1996) which require special packaging to reduce physical injury (Shewfelt 1987). The use of modified atmosphere packaging will undoubtedly play a major role in overall preservation for highly perishable products. Modified atmosphere packaging (MAP) extends the storage life by slowing respiration rate (Kader 1986). This allows fruit to maintain higher levels of organic acids and sugars which are important in their flavour profile and overall eating quality (James and Kader 1996).

Minimally processed products in MAP normally had high inpackage humidity. One serious problem associated with this condition is condensation on the film that is driven by temperature oscillations during marketing. The amount of condensate formed is related to the difference in temperature inside and outside the package, the void volume of package, and to some extent, the type of the film used (Ben-Yehoshua 1985). The presence of significant condensate could increase microbial activity and block diffusion of oxygen into submerged tissues, thus causing fermentation. Further more, high humidity may encourage disease development thus shorten the shelf life (Jeffery 1995).

In view of the above situation, an attempt was made to evaluate the effect of changes in the inpackage temperature and relative humidity in relation to the quality of minimally processed limau madu packed using thermal freeze and corrugated fibreboard packing. Physical chemical changes and sensory evaluation were also monitored to determine product quality and shelf life during storage at 25 °C and 10 °C.

Materials and methods
Limau madu (Citrus reticulate) fruits used in this study was obtained at commercial maturity from a private farm at Yong Peng, Johor Bahru. Upon arrival at MARDI laboratory in Serdang, Selangor, the fruits were sorted and washed to remove the extraneous matter from the field. The fruits were peeled, individual segments were segregated and the arils were removed.
Round polypropylene containers with the “clip-on lid” (size: 250 ml) were used for packing. One piece of water absorbent (Supersob) was placed in the polypropylene container and each pack contained 10–12 fruitlets with an average net weight of 100 g. The polypropylene containers were arranged neatly in insulated boxes (50 x 38 x 17.5 cm) layered with frozen thermal freeze (TF). Each insulated box can hold 18 containers. Six insulated boxes were used for the study. Control samples were packed in corrugated fibreboard boxes (CFB). Six TF packing and six CFB packing were used for the study. All the boxes were initially stored at 2 °C for 2 weeks. Following that, MP limau madu in the three TF and three CFB packing were transferred to 10 °C, RH 85–90% (to simulate condition at the dry market) and three TF and three CFB packing were transferred to 25 °C, RH 65–70% (to simulate condition at the wet market). Observation at 25 °C was conducted daily for 4 days, whereas at 10 °C, the observation was conducted every alternate days until day 6.

**Colour of the fruit segment**

Colour of the fruit segment of limau madu was determined using the Minolta CR300 Chromameter by measuring the value of L* (lightness ) and b* (yellowness). On the evaluation days, five packs of MP limau madu stored at 25 °C and 10 °C were taken randomly from TF and CFB packing for colour measurement. Colour was measured in five replicates from three individual fruitlets from each pack.

**Temperature and relative humidity**

Inpackage temperature and relative humidity were measured using HOBO Pro Tem/RH logger. Temperature kid (HOBO) was placed at the centre of the three TF and CFB boxes. The graph plotted was based on the average reading from three Hobo readings.

**Chemical analysis**

Minimally processed limau madu was analysed for total soluble solids by using a refractometer (Model Atago Digital DBX-5). The pH value was determined using Orion digital pH meter (Model SA520). Total titratable acidity was measured by titrating 0.1 N NaOH to an end point of pH 8.1. Ascorbic acid content was measured by titrating with 2,6 dichlorophenolindophenol (Ranganna 1977). On each evaluation day, five packs of MP limau madu, which had been used for colour measurement, was later used as samples for the chemical analysis. The limau madu juice was extracted by squeezing the fruitlets using a kitchen blender. One pack of MP limau madu represents a replicate. Chemical analyses were conducted in three replicates.

**Sensory evaluation**

The sensory evaluations were carried out by a panel of 10 fixed panellists. Five packs of MP limau madu from 25 °C and 10 °C were taken randomly from the three TF and CFB packing on each evaluation day. Three fruitlets from each treatment were put on the polystyrene tray (20 x 11cm) and given to panellists for the sensory evaluation. The panellists were requested to evaluate the MP limau madu for colour, texture, taste, aroma and overall acceptability using 7-point hedonic scale (1 = very unacceptable, 2 = unacceptable, 3 = moderately unacceptable, 4 = neither good nor bad 5 = moderately good 6 = good and 7 = very good).

**Statistical analysis**

A complete randomized design was used for the experimental set up with two packing treatments, storage temperatures and five samples replication on each evaluation (day 0, 1, 2, 3, 4 and 7). Data were analysed statistically using analysis of variance (ANOVA) (Steel and Torrie 1980) and the differences among the means were determined for significance at p <0.05 using Duncan multiple range test (SAS Inst. 1990).
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### Results and discussion

The packing system greatly influenced the temperature and relative humidity surrounding the packed MP *limau madu*. The surrounding inpackage temperature in the thermal freeze (TF) packing stored at 25 °C, remained at 0 °C for 24 h (*Figure 1*). The temperature increased to 3 °C after 36 h and reached 15 °C after 48 h (day 3). Following that, the temperature increased progressively reaching 20 °C after 60 h. At this stage, the thermal freeze was already melted. The relative humidity in TF packing remained stable at 100% throughout the storage period (*Figure 1*). Temperature and RH in the control samples (CFB packing) fluctuated from 19–26 °C and RH 55–85% respectively (*Figure 2*). Similar trend of temperature change was also observed when evaluating the effectiveness of thermal freeze packing for shelf life extension of minimally processed jackfruit, durian and pineapple (Latifah et. al. 1999a, b, 2000).

The temperature in the thermal freeze packing stored at 10 °C remained in frozen form (0 °C) for 60 h, then it increased to 3 °C after 72 h (*Figure 3*). Following that, the temperature increased and reached the storage temperature at 10 °C on day 4 and remained at this temperature until day 7. Throughout the storage period the RH remained at 100%. The temperature in the CFB packing remained at 10 °C with the RH maintained at 95%, until the end of the storage period (*Figure 4*).

The TSS value of MP *limau madu* in TF packing stored at 25 °C increased from 14.47 °Brix (day 0) to 15.03 °Brix (day 1) (*Figure 5a*) with inpackage temperature maintained at 0 °C (*Figure 1*). The increasing trend (15.3 °Brix) was further shown on day 2 when the surrounding

![Figure 2](image2.png)

*Figure 2. Changes in the temperature and relative humidity of minimally processed *limau madu* packed using corrugated fibreboard boxes (CFB) packing during storage (3 days) at 25 °C*

![Figure 1](image1.png)

*Figure 1. Changes in the temperature and relative humidity of minimally processed *limau madu* packed in thermal freeze (TF) packing during storage (3 days) at 25 °C*

![Figure 3](image3.png)

*Figure 3. Changes in the temperature and relative humidity of minimally processed *limau madu* packed in thermal freeze (TF) packing during storage (7 days) at 10 °C*
inpackage temperature was at 3 °C, indicating active chemical reaction with prolonged storage. However, the TSS value in the TF packing later decreased to 14.43 °Brix when the inpackage temperature increased to 20 °C. The reduced TSS value attained at the end of the storage period was probably related to the senescence process of the product itself as also observed in MP jackfruit (Latifah et al. 1999a; 2001b) and pineapple (Latifah et al. 1999b) The TSS content, which is an approximate measurement of the sugar content of a fruit, had shown a higher value in the CFB packing as compared to the TSS value in the TF packing as observed in minimally processed limau madu stored at 25 °C (Figure 5a). The TSS value in the CFB packing showed significant increase on day 2 attaining 15.97 °Brix (Figure 5a) coincided with the high surrounding inpackage temperature of 25 °C (Figure 2). However, the value decreased on day 3 to 15.7 °Brix, even though surrounding temperature was constant at 25 °C (room temperature). These were probably related to the amount of sugar normally been used as part of the respiratory substrate towards the end storage life of horticultural produce (Shewfelt 1987).

The lower temperature (0–3 °C) surrounding the TF packing of MP limau madu stored at 10 °C (Figure 3) had contributed to the lower TSS value (15.1 °Brix) as compared to the higher TSS value (15.61 °Brix) in the CFB packing as observed on day 3 (Figure 5a). However on day 4, significantly higher TSS value was noted for the minimally processed limau madu stored in the TF packing as compared to minimally processed limau madu in the CFB packing (Figure 5a). At the later end of the storage period (day 7), the TSS value in both packing systems was reduced with higher value shown in the CFB packing (15.43 °Brix) as compared to the TF packing (15.07 °Brix).

There was no significant difference in the pH value for the MP limau madu in the TF and CFB packing during storage at 25 °C on day 1 and day 3 (Figure 5b). There was no drastic change in the pH value of the samples both for the TF and CFB packing when stored at 25 °C (day 1 and 2). The pH value decreased at the end of the storage period (day 3). There was significant difference in the pH value of MP limau madu in the TF and CFB packing on day 2 and 4 stored at 10 °C. The pH value of MP limau madu in TF packing increased on day 2 (4.17), decreased on day 4 (4.10) and later increased to 4.16 at the end of the storage period (day 7). However, the pH value in the CFB packing remained unchanged on day 4 and day 7 (4.15) (Figure 5b).

The TTA value, which is a quantitative measure of the organic acid, decreases with senescence process (Kader 1986). However, in this study, the TTA value obtained had shown inconsistent trend both at 25 °C and 10 °C for the TF and CFB packing (Figure 5c).

Retension of ascorbic acid is often measured when evaluating postharvest storage effect on nutrients. A decreasing trend of ascorbic acid was observed during storage of MP limau madu though no significant difference was observed between
Figure 5. Changes in TTS (a), pH (b), TTA (c) and ascorbic acid values (d) in minimally processed *limau madu* packed using corrugated fibre board (CFB) and thermal freeze (TF) during storage for 3 days at 25 °C and 7 days at 10 °C.
TF and CFB packing system both at 25 °C and 10 °C (Figure 5d).

There was no significant differences in the L* value of MP *limau madu* stored at 25 °C and 10 °C throughout the storage period both for the TF and CFB packing (Table 1). A decreasing trend in the b* value was observed in MP *limau madu* stored at 25 °C for both TF and CFB packing with significant difference on day 2. However inconsistent values were noted in the b* value for samples stored at 10 °C with significant difference between TF and CFB packing shown on day 2 and day 4 (Table 1).

Besides taste, colour is one of the major quality attributes considered to have the most impact on consumer selection. Despite the changes both in the L* and b* values, the orange colour of *limau madu* was still retained until the end of the storage period. The higher b* value (22.37) retained in the TF packing stored at 10 °C indicated that the yellow colour was retained until the end of the storage period (day 7). Overall results indicated that the b* values (yellowness) of the fruitlets of *limau madu* stored at 25 °C reduced with storage duration as observed both in the CFB and TF packing. However, at 10 °C, the b* value in the TF packing increased with storage duration while inconsistent trend was noticed for *limau madu* in CFB packing. However, paler orange colour was noticed for *limau madu* packed in CFB packing after day 2 at 25 °C probably due to colour degradation that occurred more obviously at higher temperatures.

Overall acceptability of MP *limau madu* depends on the storage temperature and also packing system. At 25 °C, MP *limau madu* in the TF packing was still accepted until day 2 with high score given for the taste and overall acceptability attributes (Table 2). Combined value of TSS (15.17 °Brix) and pH (4.02) (Figure 5) probably had contributed to higher score given by the panellists (Table 2). However on day 3, lower score was given to sensory attributes especially on taste and aroma, possibly due to degradation of the fruit during storage.

**Table 1. Changes in the colour (L & b values) of minimally processed *limau madu* packed with thermal freeze (TF) and in corrugated fibreboard boxes (CFB) during storage at 25 °C and 10 °C**

<table>
<thead>
<tr>
<th>Duration of storage</th>
<th>Temperature °C</th>
<th>Treatment</th>
<th>L* (Lightness)</th>
<th>b* (Yellowness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>2</td>
<td>TF</td>
<td>52.30abc</td>
<td>21.52g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>52.30abc</td>
<td>21.52g</td>
</tr>
<tr>
<td>Day 1</td>
<td>25</td>
<td>TF</td>
<td>48.43bc</td>
<td>22.66c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>46.54c</td>
<td>22.83b</td>
</tr>
<tr>
<td>Day 2</td>
<td>25</td>
<td>TF</td>
<td>52.82ab</td>
<td>22.40d</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>52.86ab</td>
<td>21.26i</td>
</tr>
<tr>
<td>Day 3</td>
<td>10</td>
<td>TF</td>
<td>54.13ab</td>
<td>17.74k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>54.46a</td>
<td>20.38j</td>
</tr>
<tr>
<td>Day 4</td>
<td>25</td>
<td>TF</td>
<td>48.99abc</td>
<td>17.00m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>49.44abc</td>
<td>17.56L</td>
</tr>
<tr>
<td>Day 7</td>
<td>10</td>
<td>TF</td>
<td>50.36abc</td>
<td>21.58f</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CFB</td>
<td>51.49abc</td>
<td>23.28a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50.48abc</td>
<td>22.37e</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>51.83abc</td>
<td>21.40h</td>
</tr>
</tbody>
</table>

Each value is the mean from 9 fruitlets. Mean values with the same letters in a column are not significantly different at 5% level.
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which coincided with the decreasing TSS (14.4 °Brix) and pH (3.98) values. MP *limau madu* in the CFB packing was rejected at the end of day 1 with overall acceptability score of 5, even though the TSS value was higher (15.40 °Brix) and the pH value still maintained at 4.06 (Figure 5). The overall acceptability of MP *limau madu* was also lowered due to the soft texture of the fruitlets, and detection of abnormal aroma (*Table 2*). Lower RH surrounding the CFB packing reduced the moisture of the fruitlets affecting the overall appearance. MP *limau madu* stored at 10 °C was still acceptable until day 7 regardless of the packing system used with the average score in the overall acceptability at 6.5–6.7. However, the sensory panellists preferred MP *limau madu* in TF packing over those in CFB packing throughout the 7 days storage period.

**Conclusion**

Quality of minimally processed *limau madu* changed greatly with duration of storage at 25 °C and 10 °C due to the effect of inpackage temperature and relative humidity.
References


Abstrak
Suhu dan kelembapan relatif dalaman pembungkus limau madu diproses secara minimum telah dikaji untuk dikaitkan dengan perubahan kualiti semasa penyimpanan pada suhu 25 dan 10 °C. Limau madu yang diproses minimum dibungkus di dalam kotak penebat yang dilapisi dengan bekuan termal (TF) manakala pembungkusan menggunakan kotak kertas beralun ombak (CFB) dijadikan sebagai kawalan. Pada peringkat awal, suhu di dalam kotak penebat yang disimpan pada suhu 25 °C dapat dikekalkan pada 0 °C selama 24 jam dengan kelembapan relatif (RH) 100%. Suhu kemudiannya meningkat kepada 3 °C selepas 36 jam, 15 °C selepas 48 jam dan 20 °C selepas 60 jam. Pada semua peringkat, RH masih kekal 100%, manakala suhu di dalam pembungkus CFB yang disimpan pada suhu 25 °C, berubah daripada 19 ° kepada 26 °C dengan RH 55–85% sepanjang tempoh penyimpanan (3 hari). Pada suhu 10 °C, suhu di dalam pembungkus TF kekal pada 0 °C selama 60 jam, meningkat kepada 3 °C selepas 72 jam (hari 3), dan kemudiannya kekal pada 10 °C, dengan RH 100% sehingga akhir tempoh penyimpanan (hari 7). Perubahan kimia berlaku semasa penyimpanan limau madu pada suhu 25 dan 10 °C walaupun tiada perbezaan yang nyata ditunjukkan bagi nilai TSS, TTA dan asid ascorbik dengan bekas pembungkus dan suhu penyimpanan yang berbeza. Pola perubahan yang serupa juga ditunjukkan pada pH pembungkus yang berbeza pada hari pertama dan ketiga bagi sampel yang disimpan pada suhu 25 °C dan hari ketujuh bagi sampel yang disimpan pada suhu 10 °C. Perubahan pada kandungan kimia ini telah mempengaruhi kualiti dan penerimaan produk. Limau madu yang diproses minimum dan dibungkus menggunakan TF serta disimpan pada suhu 25 °C masih boleh diterima walaupun selepas 2 hari penyimpanan (48 jam). Walau bagaimanapun rasa limau madu yang diproses secara minimum di dalam pembungkus CFB tidak diterima selepas hari pertama walaupun produk mempamerkan nilai TSS yang tinggi dan peratus asid sitrik (TTA) yang rendah. Nilai RH yang rendah telah menyebabkan ulas limau menjadi kering. Limau madu yang diproses secara minimum yang disimpan pada suhu 10 °C masih boleh diterima sehingga hari ketujuh tanpa mengira jenis pembungkus. Bagaimanapun limau madu yang diproses secara minimum di dalam pembungkus TF mendapat skor penerimaan yang lebih tinggi berbanding dengan yang di dalam pembungkus CFB.