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ORIGINAL RESEARCH ARTICLE

# DYNAMICS OF POMEGRANATE FRUIT WEIGHT LOSS DURING PRECOOLING AND AMBIENT STORAGE: A SPATIAL AND TEMPORAL ANALYSIS

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**ABSTRACT**

In this paper the spatiotemporal profile of weight loss of pomegranate fruit (cv. Wonderful) was investigated during precooling and simulated shelf conditions. The effects of relative humidity (RH) inside the cold room, polyliner inside the packaging and stack orientation on fruit weight loss were studied. Weight loss during the precooling operation ranged from 0.17 to 0.25% of the initial fruit weight and was highest during precooling of stack without liner and inside non-humidified room (0.25%). It was observed that fruit weight loss in liner-based packaging was almost equivalent to room humidification. Results of the shelf life study demonstrated the importance of room humidification to preserve fruit quality. Storing fruit in a room at 95% RH minimised weight loss and best maintained fruit colour, firmness, size and chemical quality attributes of pomegranates. On the other hand, fruit stored at ambient condition (65% RH) up to 30 days had excessive weight loss (up that 29.13±1.49%), which led to shrivel, deformed appearance and considerably reduced overall visual quality.



## 1.0 Introduction

Rapid moisture loss is among the main quality problems affecting postharvest life of pomegranate fruit (Fawole and Opara, 2013; Arendse *et al.,* 2014). On top of losing marketable fruit weight, fruit that lose moisture above 5% will shrivel; this reduces their visual appeal and commercial value. Weight loss in fruit is mainly due to transpiration and to a relatively small extent due to respiratory activity (Waelti, 2010). Large vapour pressure deficit (VPD) between fruit surface and the surrounding air leads to increased rate of moisture loss.

Cooling pomegranate fruit preserves quality, but weight loss remains a challenge during cold storage (Arendse *et al.,* 2014). Humidification of the storage room, packaging fruit in plastic films, fruit coating, shrink wrapping are some of the practiced mitigation measures to moisture loss. However, humidification can also cause several storage problems affecting fruit. For instance,



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during cold storage of table grapes, humidification increased stem dehydration, browning of berries, increased the incidence of $SO_2$ injury and package wetting (Ngcobo *et al.,* 2013).

Temperature and humidity control in a stack of fruit is normally based on measurements taken from specific locations in the storage room. However, these have been reported to be spatially non-uniform in fruit pallets (Ambaw et al., 2017; Mukama et al., 2017). The amount of weight loss and the degree of spatial variation in the precooling process of pomegranate fruit are not clearly understood. Therefore, the objectives of this study were to: 1) measure the spatial and temporal weight loss profile during precooling of pomegranate fruit, 2) study the effects of internal packaging, humidification, and package orientation on the moisture loss, and 3) investigate the physico-chemical quality attributes of pomegranate fruit stored at different shelf conditions.

## 2.0 Study Description

### 2.1 Fruit

Pomegranate fruit (cv. Wonderful) were harvested at commercial maturity from Merwespont farm in Bonnievale (33°58’12.02” S, 20°09’21.03” E), Western Cape, South Africa and transported in an air-conditioned vehicle to Postharvest Technology Research Lab at Stellenbosch University.

### 2.2 Package materials

In this study, corrugated fibreboard carton box (CFC) was used to contain the pomegranate fruit. The box had 6 semi-circular vent-holes on the long side located at the top and bottom rim of the side, 2 semi-circular vent-holes at the top rim of the side and 5 circular vent-holes on the bottom side. Each box contained 12 fruit with average weight of 4.32 ± 0.39 kg per carton. Fruit weight loss during precooling of two different package designs was investigated: package with internal polyliner and another without polyliner. Plastic wrapping was done by placing pomegranates in a single non-perforated 10 µm thick high density polyethylene (HDPE) plastic film.

### 2.3 Air suction equipment (ASE)

The ASE was a box with suction fan attached to one end. The suction was generated by using a centrifugal fan (KDD 10/10 750W 4P-1 3SY, AMS supplies, Sandton, South Africa). The stacked fruit, as covered with plastic sheet, was placed in front of the ASE so that air was drawn horizontally through it.

### 2.4 Cold storage room

The ASE/stack assembly was placed inside a 20 m3 cold storage room equipped with a cooling unit and a humidifier. The cooling unit had three evaporator fans each creating an air circulation rate of 1290 m3 h-1. Cold room humidity was controlled using Aqua Room-2 humidifier (Miatec Inc. 9480SE, Lawnfield Road, Chackamas OR 97105 USA) with 1.4-2.1 bars pressure capacity, 2 L h-1 liquid capacity, 10 µm droplet size and digital hygrotransmitter sensor (0-100% RH).

### 2.5 Experiments

#### *2.5.1 Precooling experiments*

70 cartons were stacked (7 layers of 10 cartons) on an ISO standard pallet (1.2 m × 1.0 m × 0.1 m). The stack was first equilibrated to ambient air conditions (≈ 17 °C and 65% RH) before being placed inside the cool storage room. The sides and top of the stack were covered with plastic sheet so that chilled air was horizontally sucked through the stack by the ASE. Two different

pallet orientations with respect to the ASE were considered: pallet with its 1.2 m side perpendicular to the air flow and pallet with the 1.0 m side perpendicular to the air flow. Due to difference in vent-hole proportion between the long and short side of the box, the vent area along the flow direction of the two different orientations are dissimilar. For the 1.2 m oriented stack, the vent-hole ratio along the flow direction were 9.45% and 2.15% at inlet and outlet, respectively. The 1.0 m orientation had vent-hole ratio of 4.24% at both the inlet and outlet end.

All precooling experiments were from the initial ambient condition (≈ 17 °C) down to 7 ± 1.2 °C. During the experiment fruit pulp temperature was monitored at intervals of 5 minutes using T-type thermocouples and a 34970a Data Acquisition/Data Logger Switch Unit (Agilet Technologies, Santa Clara CA 95051, USA). The measured temperature data was used to calculate the stack average 7/8th cooling time which determined the time to stop the precooling experiment. Additionally, fruit weight loss was measured by taking initial and final weight of sample fruit. The temperature and weight loss sampling positions were from stack levels 2, 4, and 6. A total of 24 measurements (2 pallet orientations × 2 RH conditions × 2 liner conditions × 3 repetitions) were taken.

#### *2.5.2 Measuring the effect of humidity on shelf life of pomegranate fruit*

Two groups of 216 fruit each were equilibrated to ambient condition before the start of the experiment. Group 1 was kept under high humidity condition (95 ± 1.23 %RH) and group 2 under low humidity condition (65 ± 6.79 %RH). In both cases, the room temperature was kept at 20 ± 0.36 °C. Fruit weight, colour, firmness, size, titratable acidity, total soluble solids and pH were assessed on a 3 day interval for 30 days.

### 2.6 Statistical analysis

Statistical analysis was done using Statistica software (Statistica version 12, StatSoft Inc., Tulsa, USA). Mixed model repeated measures analysis of variance (ANOVA) was done using the VEPAC module of Statistica 12 at 95% confidence interval. Variations in weight loss were compared between the package designs, stack levels, stack orientations and fruit position within a stack level. Statistical significance of the treatments was tested using Duncan’s Multiple Range Test and means with $p < 0.05$ were considered significant.

## 3.0 Results and Discusions

### 3.1 Weight loss during precooling of pomegranate fruit

On average, weight loss ranged from 0.17 to 0.25% of the initial fruit weight. Clearly, fruit weight loss was highest (0.25%) for the stack without liner and in a non-humidified cool store (“None” in Fig. 1 (a)). Stack with plastic liner and in a humidified room (“Liner + Humidification” in Fig. 1 (a)) experienced the lowest weight loss (0.17%). However, the presence of liner always increased fruit cooling time (Fig 1(b)) such that stacks with liner had SECT higher than 10 h compared with less than 5 h for stacks without liner.

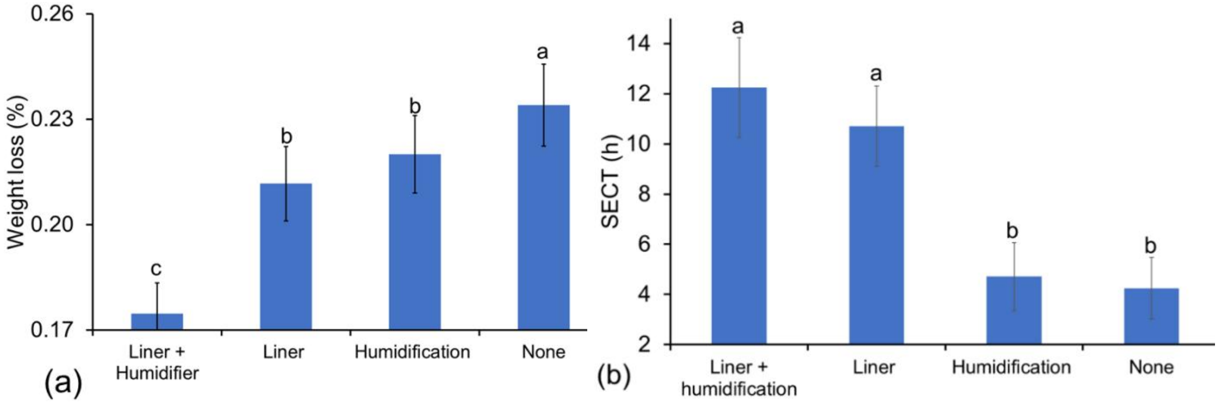


Fig. 1. Weight loss of pomegranate fruit (mean ± STDV) during precooling (a) and the corresponding 7/8th cooling time (SECT (b). All humidification was at 95 ± 1.23 %RH. When no humidification, the cool storage room was kept at ambient humidity condition of 65 ± 6.79 %RH. The weight loss and SECT values are stack means. Means with different letters are significantly different ($p < 0.05$).

### *3.1.1 Effect of stack orientation*

The average weight loss of precooled pomegranates in the 1.0 m orientated pallet was 0.20% while those in the 1.2 m oriented pallet it was 0.22%. The 1.0 m side of the pallet has relatively lower ventilation compared to the 1.2 m orientation as described in section 2.5.1. Low ventilation rate results in relatively lower convective mass transfer coefficient from the fruit surface to the ambient air. This leads to the observed low weight loss profile. However, this also leads to a relatively higher cooling time.

### *3.1.2 Spatial variation in weight loss*

Spatial variability of the weight loss is important to identify the high and low weight loss regions. Fruit in the upstream region received the chilled air first, thereby subjecting them to a faster cooling rate. Increase in air temperature as it moves across a stack causes local variations in heat loss in the stacked products (Baird *et al.,* 1988) and holding pomegranate fruit at higher temperatures for longer period causes higher moisture loss rates. There was no significant difference in weight loss between layers of the stack in all cases.

## 3.2 Effect of humidity on shelf life quality of pomegranate fruit

### *3.2.1 Weight loss and fruit shrivel*

Pomegranate fruit continuously lost weight throughout the shelf life period. Till day 3, there was no significant difference between the two RH environments. However, fruit weight loss under the low RH environment became significantly higher starting from day 6, with losses reaching up to 29.13±1.49% in the low RH environment compared to 5.78±0.44% in the high RH environment. This shows that the high RH environment reduced the vapour pressure deficit (VPD) between the fruit and the environment, resulting in a significantly reduced moisture loss from the fruit (Ngcobo *et al.,* 2013).

Shrivel was observed on fruit from the low humidity environment on day 6. At this stage the average weight loss was 5.28 ± 0.32% of its initial weight, and by day 9, the dents on the fruit surfaces were larger. Shrivel is due to loss of turgor pressure in the fruit cell walls as they continuously lose moisture (Paull, 1999). Under high humidity environment, some fruit slightly shriveled on day 24.

Changes in fruit colour, size, firmness, titratable acidity, pH, and total soluble solids were more significantly pronounced in the low humidity storage environment than high humidity environment (Fig. 2)


Fig. 2. Visual condition of pomegranate fruit 30 days under ambient humidity condition, RH ≈ 65% (top row) and under humidified condition, RH ≈ 95% (bottom row).

## 4.0 Conclusion

This study investigated the level of reduction of weight loss achievable by employing liner-based packaging or room humidification. This study also quantified the spatial variation in weight loss of pomegranate fruit during precooling operation. Fruit at the back of the stack had higher weight loss than those at the front. This goes in parallel with the temperature distribution in the stack as reported in previous studies (Ambaw et al., 2017 and Mukama et al., 2017). The shelf life study showed the importance of room humidification as a cold chain strategy to maintain pomegranate postharvest fruit quality. Storing fruit under 95% RH maintained fruit colour best, minimised weight loss, maintained fruit firmness, fruit size and the chemical quality attributes of pomegranates. Storing fruit under low RH ambient conditions led to excessive weight loss, which in turn resulted in excessive shrivel, deformed appearance, and reduced visual quality of fruit. These findings can be applied in efforts to establish the best storage conditions of pomegranates to maintain quality and reduce incidence of postharvest losses along the value chain from harvest to consumers.

## 5.0 Acknowledgement

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