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Microclimate tools to monitor quality changes in stored onions

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Abstract

Losses of onion are caused by spoilage from microbial infection, sprouting, and mass loss. Pre-harvest factors such as cultivar, climate, growing condition, as well as harvesting, curing, storage duration, temperature and relative humidity during storage influence losses. The optimal storage conditions for onions are 0 °C and 65% - 75% relative humidity (RH), however, it is costly to store onions at this low temperature for long times. It can also be challenging to maintain low RH at low storage temperature. The aim of the present study was 1) to test the applicability of a HortiSens® sensor to monitor temperature and RH at experimental conditions and to evaluate the effects of 2) conventional and pulse cooling, and 3) low and high RH during storage on the quality of conventionally- and organically-grown onions.

We found that online microclimate monitoring using the novel wireless HortiSens® sensor gave similar results as data from the other sensors. Onions had higher basal root sprouting with pulse cooling and after storage in high relative humidity. There was higher incidence of diseases at high RH but lower mass losses. Organically-grown onions had higher incidence of root sprouting and diseases than conventionally-grown onions especially during storage in high RH.

Keywords: temperature, relative humidity, mass loss, root sprouting, diseases, organic, conventional

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important vegetable crops worldwide. Typically, onions are grown on a large scale and cured, dried and stored at farm level before being distributed to the market (Brewster, 2008; Rabinowitch and Currah, 2002).

Pungent onions with a high dry matter content are suitable for long term storage as they tend to be more resistant to pathogens than less pungent, softer and more juicy onions (Rees et al., 2012). During storage, onions respire and transpire and lose part of their mass. Proper storage is essential to maintain dormancy and to delay top and basal root sprouting (Apeland, 1969), especially in organic production where sprout inhibitors are not allowed.

Optimal storage conditions and tools to monitor storage climate play a major role in maintaining onion quality. It is possible to store onions at high temperature (25 - 30°C) which maintains dormancy and inhibits top sprouting but high temperature also increases respiration

rates, desiccation, and rotting (Stow, 1975; Ward, 1976) and leads to high mass losses. Onions can also be stored at temperatures below 10 °C and it slows down the biological processes (Brewster, 1987). Watkins and Nock (2012) recommend storing onions at 0 °C and 65%-75% relative humidity (RH), however, it is costly to store onions at this low temperature for long times and it can be challenging to maintain low RH at low storage temperature. Different storage techniques are used in Denmark ranging from low and stable temperatures (~0 °C) at high RH (> 90%) to high and variable temperatures (4-10 °C) at low RH (80-85%). Overall, farmers are interested in optimizing the storage conditions to reduce losses while keeping costs low.

In commercial storage, temperature and RH are monitored inside rooms or in the outlet ventilation system with wired sensors. This information is used for control of the storage microclimate but it is of general character and does not give information on the microclimate in the vicinity of the produce. Recently, a HortiSens® sensor was developed which gives continuous, automatic and up-to-date information on the microclimate.

The aim of the present study was 1) to test the applicability of a HortiSens® sensor to monitor temperature and RH at experimental conditions; and to evaluate the effects of 2) conventional and pulse cooling, and 3) low and high RH storage on the quality of conventionally- and organically-grown onions.

MATERIALS AND METHODS

Plant materials

Two experiments were carried out with onions grown in 2012 and in 2014. In the first experiment, three batches of conventionally-grown onions and three batches of organically-grown onions were harvested, cured and stored at two farms (one conventional and one organic) and then brought to Dept. of Food Science, Århus University (AU) for storage experiments in Spring 2013. In the second experiment, two batches of conventionally-grown onions and two batches of organically-grown onions were harvested, cured and stored at these same two farms in 2014 and then brought to AU for storage experiments in Spring 2015.

Storage condition

In a first experiment, onions were stored at conventional/normal cooling at ~0.5 °C and at pulse cooling ranging from 2.5 °C to 4 °C in two storage chambers (120x95x109 cm). In the second experiment, onions were stored at 4 °C at low (~75%) RH and at high (>90%) RH in the same size chambers as in the first experiment. In each experiment, six samples of each batch of first class onions (40 onions per sample in a box; diameter ≥ 40 mm) were prepared and half of the samples were placed in one storage chamber and the other half in the other chamber. Before the chamber was filled, all samples were randomized and placed in randomized order in the chamber. The first experiment was running from March 1 to April 10, 2013 and the onions were transferred to shelf-life evaluation at 22 °C until May 3, 2013. After storage, mass loss, basal root sprouting and diseases were evaluated while top sprouting was evaluated after storage in shelf-life. In the second experiment, samples were taken as for the first experiment and stored from March 10 to August 28, 2015. Mass loss, top and basal root sprouting and diseases were evaluated directly after storage.

Temperature and RH

For the first experiment room temperature sensors were used throughout storage. In the

second experiment two other sensors were used; 1) MSR temperature and RH loggers (MSR Electronics GmbH, Switzerland); and 2) wireless temperature and RH HortiSens® sensors (Webstech, Kongskilde, Denmark). The MSR temperature and RH sensor was calibrated before use and used throughout storage while the HortiSens® sensor was used with the calibration of the manufacturer and used only during the last part of storage from 12 June to 11 August 2015.

Statistical analysis

Experimental data were subjected to one way analysis of variance (ANOVA). Principal component analysis was carried out in Origin Pro 9 (Origin Lab Corporation, USA). Significant differences between mean values were determined by Tukey's multiple range test at $P = 0.05$.

RESULTS AND DISCUSSION

The average storage temperature was 0.2 ± 0.5 °C for normal cooling and 3.0 ± 0.4 °C for pulse cooling (data not shown). The variation in temperature was greater with pulse than with normal cooling; ranging from 1.3 °C to 4.5 °C with pulse cooling and from -0.4 °C to 1.1 °C with normal cooling. The average temperature in second experiment with the MSR loggers was almost similar for the low and the high RH chamber. It was 3.9 ± 0.13 °C with low RH and 4.0 ± 0.26 °C with high RH (data not shown). With the HortiSens® sensors, results were opposite as the highest temperature was measured in the low RH chamber (4.5 ± 0.45 °C) and the lowest in the high RH chamber (4.3 ± 0.06 °C) as shown on Figure 1. Regarding RH, average MSR readings showed $72.5 \pm 0.8\%$ in the chamber with low RH and $99.3 \pm 0.4\%$ with high RH. In comparison, the HortiSens® sensor showed $75.3 \pm 4.0\%$ in the low RH and $96.1 \pm 0.4\%$ in the high RH chamber. Variation between the measured values was due to different positions of the sensors inside the storage chambers and to different periods of measurements.

The organically grown onions had higher mass losses than the conventionally-grown onions in both experiments (Figures 2 and 3), regardless of storage condition. Top sprouting, root sprouting, and disease incidence was also higher for the organically-grown onions than for the conventionally-grown onions regardless of storage conditions, except at low RH where root sprouting was not observed in the onions (Figure 3). It is known that abrupt changes from cold to ambient temperature can trigger sprouting of onions bulbs (Benkeblia and Selselet-Attou, 1999; Benkeblia and Shiomi, 2004). In experiment two, the conventional onions were stored at higher temperatures (4 - 10 °C) than the organic onions (~ 0 °C) at the respective farms before being moved to AU for storage experiments, which could have triggered sprouting of the organic onions. However, organically-grown onions were not sprayed with sprout inhibitors in the field so it was expected that these onions readily developed top sprouts during prolonged storage (Figure 3). Higher incidence of top-sprouts can increase the mass loss due to increased evaporation of water through the sprout tissue.

Low RH during storage resulted in higher mass losses than storage at high RH (Figure 4). Similar results were reported by Van Den Berg and Lentz (1973), who found that onions stored at low (75-85%) RH lost 0.8% of the mass each month while at high (98-100%) RH the mass loss was 0.15% per month. Komochi (1990) recommends that onions should be stored below 70-75% RH, because high RH promotes basal rooting (McDonald et al., 2004). We also observed higher basal rotting at high than at low RH and a clear separation between the organic batches at high RH (Figure 3). Suojala (2008) also reported that high RH during storage increased the incidence of basal root sprouting. At a RH above 85%, the onion basal plate becomes damp, regardless of temperature, and this initiates root sprouting (Snowden, 2010). Interestingly, pulse cooling resulted in higher percentages of basal roots compare to normal cooling (Figure 2), which might have been linked to a higher dampness of the basal plate during cooling circles.

With pulse cooling, the temperature varied from 1.3 °C to 4.5 °C while it varied from -0.4 °C to 1.1°C with normal cooling.

Postharvest losses of onions are mainly caused by spoilage from microbial infection, sprouting and mass loss (Walcott et al., 2002). In the present experiments, the total percentages of onions with diseases are given in Figure 2 and 3. Different symptoms of diseases were identified such as blue mold (*Penicillium* spp), basal rot (*Fusarium oxysporum* f. sp. *Cepae*), neck rot (*Botrytis allii*), slippery scale (*Pseudomonas gladioli* pv. *alliicola*) and sour skin (*Pseudomonas cepacia*) based on visual symptoms (Snowden, 2010). Overall, high RH humidity resulted in more root sprouting and higher incidence of diseases especially in the organic onions which also had high incidence of top sprouts (Figure 4). From literature we know that elevated temperature and high RH at storage promote diseases (Wall and Corgan, 1994; Wright, 1993). Each pathogen species has its own temperature requirements for growth and development but all pathogens grow at high RH (>80%) (Rees, et al., 2012). Therefore control of RH is a paramount to reduce storage losses if onions are grown organically.

CONCLUSIONS

Wireless HortiSens sensor has the potential to be used as online microclimate monitoring tool. We found higher incidence of diseases and higher mass losses with high RH while higher incidence of basal root sprouting with pulse cooling together with high RH at storage. Moreover, organically-grown onions showed higher incidence of root sprouting and diseases than conventionally-grown onions.

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Figure 1: Data from the HortiSens sensor from 12 June 2015 to 11 August 2015.

Figure 2: Effect of normal cooling and pulse cooling on onion quality. Three batches of conventional and three batches of organic onions were tested in triplicate.

Figure 3: Effect of low and high relative humidity on onion quality. Two batches of conventional and two batches of organic onions were tested in triplicate.

Figure 4: A PCA biplot for onions stored under low (L) and high (H) relative humidity (RH).

B: batch; R: replicate. Batch 7-8: conventional; batch 9-10: organic.