# Air circulation management in CA storage of apples based on airflow measurements


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**There is a high potential for saving energy in fruit cool stores by optimizing air circulation management based on actual measurement of the airflow close to the produce. The aim of the study was to determine the influence of varying fan speed on the airflow pattern in an CA-apple storage room. Therefore, measurements of an air velocity profile in one vertical gap between the apple bins and of air velocity inside bins between the fruit were performed.**


## Storage room

- CA apple storage room (50 t)
- Air cooler (type Helpman, LFX 256-7 230-E4, 5 fans) with sealing-off
- Outlet air velocity 3 $ms^{-1}$
- Stack of 163 bins (1.0 m x 1.18 m x 0.75 m) filled with ~300 kg fruit
- Gap distance of about 13 cm between three bin rows

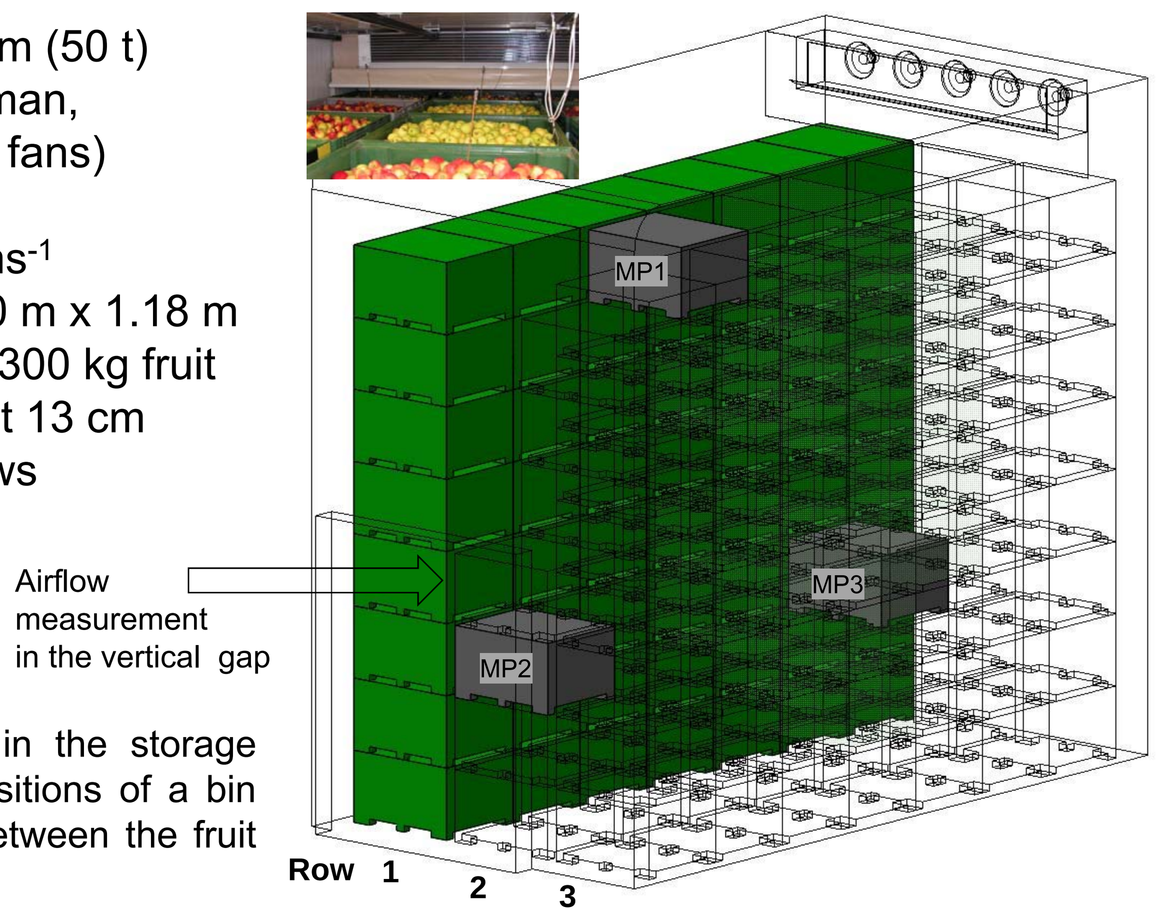


Fig. 1: Stacking layout in the storage room with measuring positions of a bin with an airflow sensor between the fruit (MP1-3)

## Test procedure

- Temperature set point at 1°C, precooled apple bins before the test
- 30 Wireless anemometers attached to the side wall of the bins of row 1 for measurement in the vertical gap between row 1 and 2 (Fig. 1,2a)
- Airflow measurement in vertical or horizontal direction by turning the anemometers by 90° between two subsequent measurements
- Airflow measurements inside a bin at three measuring positions in the stack (MP 1,2,3) with a non-directional thermal anemometer (Fig. 1, 2b)
- Four fan speed levels (25%, 50%, 75%, 100%), measurement time 10 minutes

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Fig. 2: Airflow measurement a) in a vertical gap, b) inside a bin

## Airflow profile in the vertical gap

The average air velocity in the gap varied between 0.3 m $s^{-1}$ and 2 m $s^{-1}$ at 100% fan speed with an average of 1.02 m $s^{-1}$ (Fig. 3). For 75% and 50% fan speed the average dropped to 0.66 m $s^{-1}$ and 0.32 m $s^{-1}$, respectively. Because the first generation of wireless anemometers had only a poor sensitivity below 0.4 m $s^{-1}$, measurements at 25% fan speed could not be evaluated.

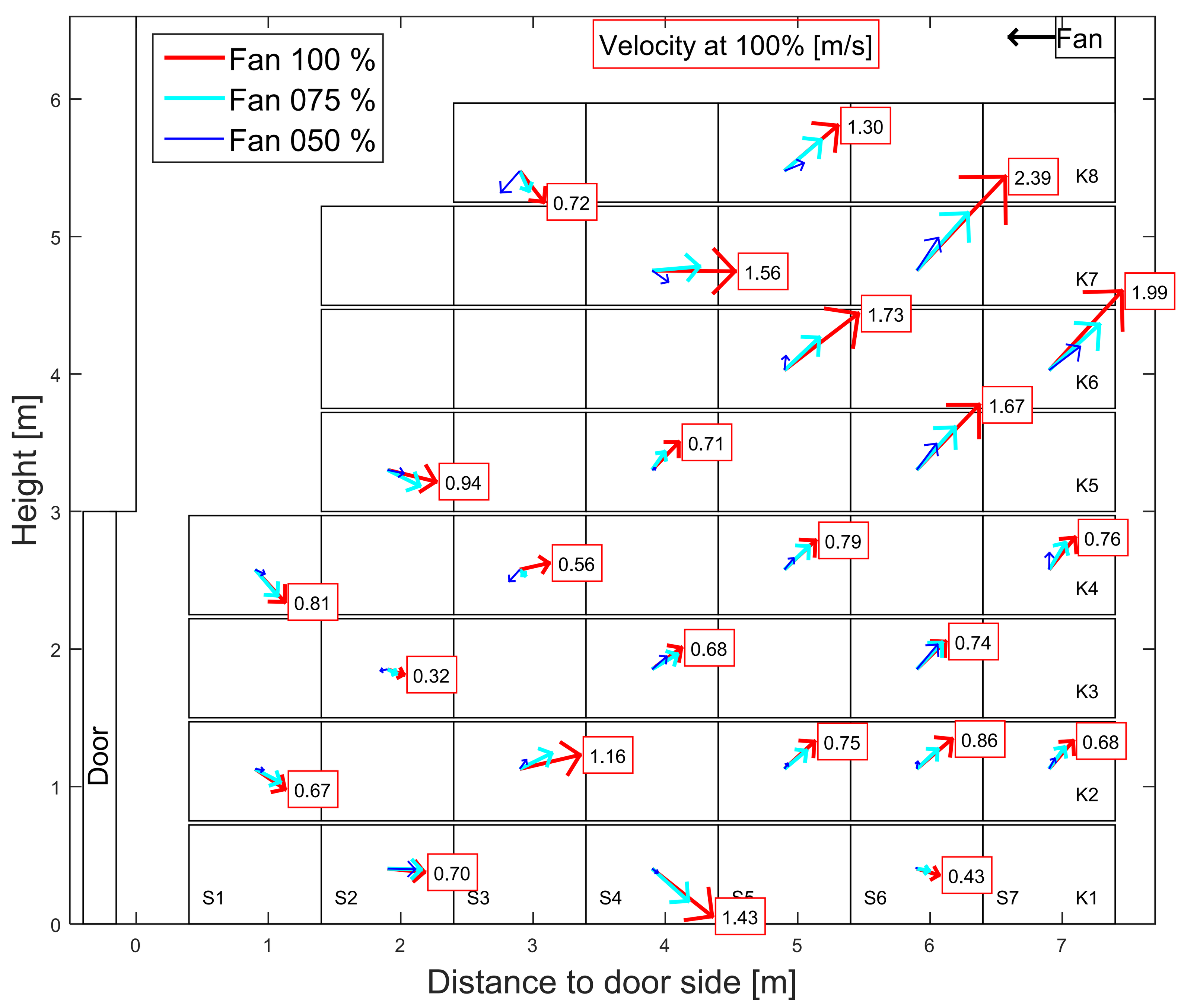


Fig. 3: Angle comparison of airflow in the gap between row 1 and 2 at different fan speed

## Airflow inside the bins

Changes of the fan speed had an immediate impact on the airflow between the fruit in the bins.
At 100% fan speed the air velocity between the fruit in the bin at the position MP2 fluctuated between 0.025 m $s^{-1}$ and 0.055 m $s^{-1}$. These fluctuations decreased with reduced fan speed (Fig. 4).

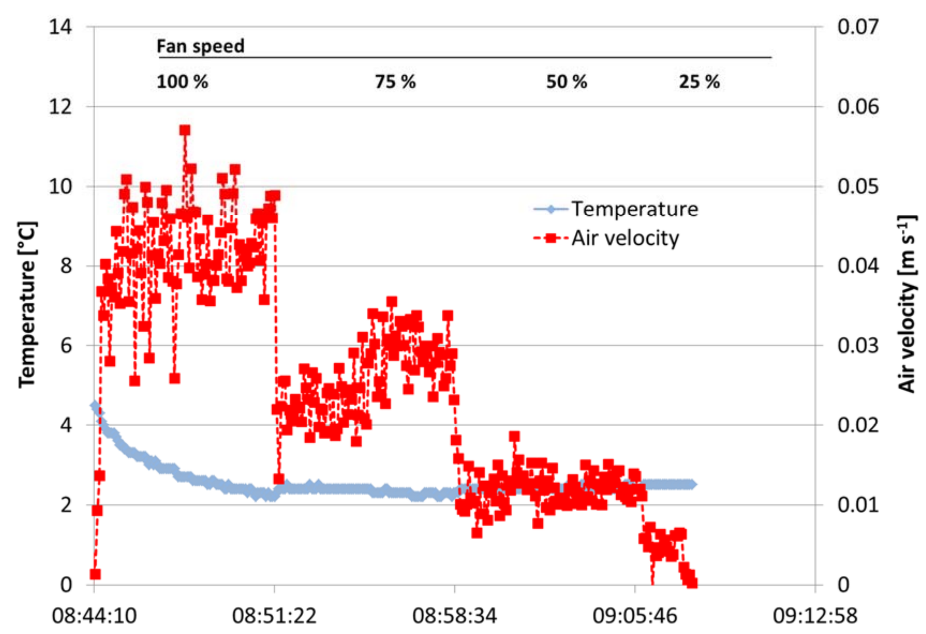


Fig. 4: Air velocity inside the bin at position MP2

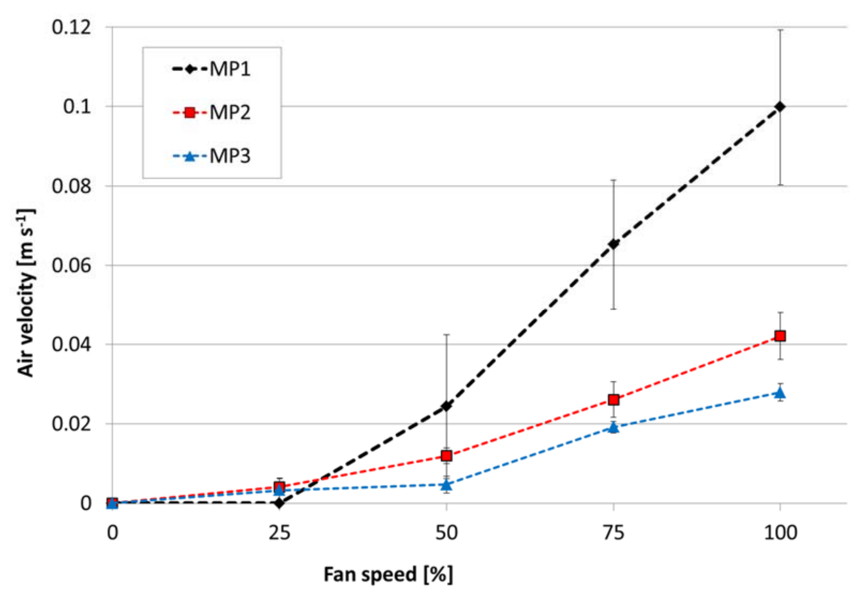


Fig. 5: Air velocity inside a bin at the positions MP1,2,3 in the stack

Low average air velocity of ≤ 0.1 m $s^{-1}$ was measured between the fruit (Fig. 5). The average air velocity between the fruit was much higher in position MP1 at the top of the bin stack compared to the bin positions MP2 and MP3. The average air velocity inside the bin decreased almost linearly with reduced fan speed. At 25% fan speed only negligible air velocity was measured.

## Fruit quality after storage

No negative impact on fruit quality was found (firmness, TSS, acidity) after the storage period of 7 months between October and April of 'Jonagold' apples with 50% fan speed compared to 100%.

**The lowest airflow in the gap was measured in the bottom corner below the fan. The airflow might become insufficient in the area at 50% fan speed. Detailed measurements are planned with next generation wireless anemometers with higher resolution.**
**Airflow inside the bins strongly depended on the bin position. At 100% fan speed average air velocity between fruit was about 3-fold higher than at a low position inside the bin stack. Airflow between fruit was reduced at 50% and 75% fan speed but might be sufficient in order to ensure quality maintenance of the stored fruit. First results of a quality assessment after storage with reduced fan speed of 50% indicated that the apple quality was not impaired. Recommendations for required air velocity next to the products of 0.1 to 0.2 m $s^{-1}$ should be verified.**


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Supported by: Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag